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SPEECHES AND PANEL TALKS

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Purpose of the Seminar

To discuss mutual problems of public and private agencies in improving and developing equipment for soil management and to formulate methods and procedures for cooperative effort in future developments.

PROCEEDINGS OF SEMINAR ON TILLAGE AND TRACTION EQUIPMENT RESEARCH

Thursday Morning, October 24, 1957, Duncan Hall

Meeting called to order by Chairman, Dr. A. W. Cooper.

Dr. Cooper: Gentlemen, the meeting will come to order. If we are going to have the good fortune and pleasure of being welcomed by our President of the Alabama Polytechnic Institute today, we want to get under way because he has a "flying" trip to Atlanta just after we get started.

We are certainly delighted to see this group here today. We have diverse training but we are all interested in the same thing. First, I think we should state the purpose of this meeting. The purpose of this Seminar is to discuss the mutual problems of public and private agencies in improving and developing equipment for soil management and to formulate methods and procedures for cooperative effort in future developments. We hope that out of this meeting will grow not formal rules or organization but cooperative effort in engineering research to help us do a better job for agriculture.

First on the program, we are very fortunate to have Dr. Draughon, President of Alabama Polytechnic Institute, to welcome this group. Dr. Draughon is a native of Alabama, a distinguished historian, an authority on Alabama history, and the reason we are so delighted to have him today is that he is a good friend of agriculture and of engineering.

<u>WELCOME</u> by R. B. Draughon, President of the Alabama Polytechnic Institute.

Thank you very much Dr. Cooper and gentlemen. It is a very great pleasure for me, as President of the Alabama Polytechnic Institute, to extend to you a very cordial and hearty welcome to our campus for these important seminars. I have been very much excited over the prospects of these meetings because, as they were in their planning stage, I was consulted, and I was entirely enthusiastic over what seems to be the possibilities of such a group of seminars with such a representation. I think I should, on behalf of Auburn, express my thanks to the Agricultural Research Service of the United States Department of Agriculture for its sponsorship of these seminars, and say that we are particularly delighted to have the representatives of that Service with us for these meetings. I would also like to welcome our colleagues from the other land-grant institutions in this area who are here for these meetings. I am sure that these gentlemen will be in position to make many fine contributions toward the achievement of the purposes which are so well stated here in the program. Then, too, because of the very fine relationship which exists between this Institution and the various industrial groups who are interested in these problems, I would like to say to the gentlemen who here represent private industry that we are delighted to have you with us.

I do regret that, because of another assignment, I cannot be present for these meetings. I am a member of the council, which is a sort of an executive committee, of the Commission on Higher Institutions of the Southern Association of Colleges. That is our regional accrediting body. Our Executive Secretary, who manages the accreditation procedures of the Association, is resigning to accept the Presidency of Oglethorpe University in Atlanta, so the council was called together in Atlanta today to select his successor. I am deeply sorry that that duty, which I feel I must take part in, will prevent my attendance of these seminars. I am sure that there will be much of tremendous interest not only to the people here in Alabama but to industry and to the people throughout the

The community of interest of public and private agencies in soil management equipment is aptly stated in the "Purpose of the Seminar". I find that people in agricultural-related industries usually have a working knowledge of the research role of the Agricultural Research Service of the United States Department of Agriculture. I frequently find a less well defined notion as to the role of the Land-Grant College, particularly as to the relationship of its Experiment Station to the USDA and as to the respective responsibilities and relationships of its Experiment Station and Extension Service. I am happy, therefore, to have this opportunity to talk with you about the role of the Land-Grant College in agricultural research and education. I shall confine my remarks to broad principles with the full knowledge that the specialists who follow will discuss the detailed problems of improving and developing soil management equipment.

The Land-Grant College is a unique instrument in higher education. It has even been referred to as a unique experiment in higher education. It might be well to examine the ingredients of its uniqueness. First, its creation as a public college was made possible by an Act of the National Congress which granted public lands to the several States and Territories for that purpose. Secondly, it was created to provide an education for the masses as contrasted to the older universities which had provided for the relatively few. Thirdly, the Land-Grant College was created to train people in the practical pursuits of agriculture and the mechanic arts as contrasted to the classical university education.

Thus, one of the principal functions of this new kind of institution was to teach scientific agriculture. Unfortunately, the professors soon found that they had little science applicable to agriculture and so they began to experiment. This recognition of need for research information on which to base a scientific agricultural curriculum led to the passage of a second important Act by the National Congress. This was the Hatch Act of 1887 which provided that "A department to be known and designated as an agricultural experiment station be established at a Land-Grant College in each State".

The early professors and researchers at the Land-Grant College were ever mindful of the college's responsibility to the masses and sought means of extending the results of their experiments to the farmers who, of course, were not formal students at the college. Without going into detail, suffice it is to say that again recognition of specific need resulted in the passage of the third Act by the National Congress relating to the organization and functioning of the Land-Grant College. This was the Smith-Lever Act of 1914 which provided for the establishment of the Cooperative Extension Service for Agriculture and Home Economics.

The Land-Grant College, then, is unique in that it was created by Acts of the National Congress and is supported in part by Federal grants, yet it is a State institution. Its role in agricultural research, resident instruction in agriculture, and agricultural extension education were charted in the three basic Acts which created it.

Since 1887, research in agriculture and related areas has been recognized as one of the major functions of the Land-Grant College. As you all know, agricultural research is also an important function of the United States Department of Agriculture. The question of how liaison, cooperation, and even coordination of the publicly-supported Federal and State research programs are accomplished is one that often puzzles persons outside the public agencies. This conference affords us an excellent opportunity to see this liaison in action.

The Tillage Laboratory is a Federal installation manned by a Federally employed and controlled staff. The entire staff of the Laboratory, however, is listed as USDA cooperators in the Agricultural Engineering Department section of our college catalog. Professor Kummer and other members of our agricultural engineering staff are recognized as collaborators by the Laboratory. Our own staff is engaged in research on problems that have been emphasized by farmers and others in the State as being of major local concern. Since agricultural and biological problems seldom recognize political boundaries, our research staff frequently joins with research staffs of neighboring State

Experiment Stations in a coordinated attack on problems of regional significance. Of course, Federal research agencies also frequently participate in regional research.

Now let's get back to this conference. The problems of soil-implement relations are not restricted to a single State or region. An inkling of a recognition of this fact probably was as much responsible for a Land-Grant College suggesting that the Tillage Laboratory be established as a Federal installation as was the lack of State funds. Certainly the increasing recognition of this fact with time was responsible for its gradual growth into a National Laboratory. Concentration on research problems of widespread application by the Laboratory is one of the best exemplifications of Federal research. Although much industry research and development seek proprietary results, in the area of soil-implement relationship the importance of cooperation and understanding between public and private agencies is clearly indicated. It is good, therefore, that representatives of industry and public agencies have gathered for this conference at a Federal Laboratory on a Land-Grant College campus.

The Land-Grant College has another and even more unique role in this broad field of agricultural education. This is the rôle of resident instruction or classroom teaching in the various professional curricula of agriculture. Although many different kinds of colleges and universities train mechanical and electrical engineers, very few other than Land-Grant Colleges train agricultural engineers. Even more institutions train economists and chemists but hardly any other than Land-Grant Colleges train agricultural economists, soil chemists, soil physicists, agronomists, and agricultural chemists.

Since the Land-Grant Colleges play a unique role in higher agricultural education and since agricultural industries and agricultural businesses are increasingly interested in employing personnel with agricultural training, let's look at the record and try to see how well the Land-Grant Colleges are succeeding in this role. The record isn't encouraging. In an annual enrollment study by the Resident Instruction Section of the Land-Grant College Association, the enrollment in agriculture for the fall quarter of 1956-57 was 2.4 percent greater than a year earlier as compared with a 4.8 percent increase in total enrollment. Furthermore, there were almost 1,000 fewer freshmen in agriculture than a year earlier.

We'll likely hear a lot about soil erosion during this conference. If this erosion of college agricultural student bodies is allowed to continue, the inevitable result will be an erosion in agriculture's human resources which will affect the business part of agribusiness as well as the direct agricultural part. It behooves us to attempt to discover the causes of the decline in agricultural enrollments; to attempt to anticipate future needs; and to develop plans for recruiting and training a sufficient number of boys to fill the needs.

The cost-price squeeze is a very real thing in American agriculture. There's no doubt that it is playing an important part in many a high school graduate's decision not to take agriculture in college. A farmer who has to make a great sacrifice to send his boy to college may not encourage him to take agriculture. The same is true for the vocational teacher or 4-H Club leader who may feel that he is underpaid as compared to some classmate who took engineering, for example. As real as these factors are, I'm afraid that we've used the word "problem" too often in connection with agriculture when "opportunity" or "challenge" would have been more effective.

If we believe that this decline in enrollment is a national "problem" and thereby presents a "challenge", then we in the colleges and USDA and you in industry can cooperate to solve the problem and meet the challenge. We can strengthen and modernize our curricula. We can do more to attract outstanding rural high school graduates into the agricultural college. Industry has even more potent means of recruitment than we. In my youth, the electrical industry advertised electrical appliances in our college paper; for years, however, this same industry has advertised not fans but employment opportunities for electrical engineers and electronics experts. On the other hand, I note the

country and around the world which would be tremendously interesting to me because of my own interest in history and the things that people do to develop our civilization.

I hope that your stay here and that these seminars will be pleasant to each of you and entirely profitable both to you, to the Department of Agriculture, and certainly to the Alabama Polytechnic Institute. I have looked through your program and I feel that it is a very good one. I don't see any space reserved for a discussion of earth satellites and sputniks and that sort of thing, but I have no doubt that in the course of your discussions maybe even those items will be included. I am indebted to Dr. Coyt Wilson for a story about sputniks that I will pass on to you. I'm sure many of you may have read it but I thought it was right cute. It is said that the American satellite, which will contain all of the communications equipment and that sort of thing that is necessary, will be the size and shape of a golf ball, and it will be called "putnik."

We are happy to have you with us, gentlemen, and I wish you entire success and pleasure in these meetings. Thank you very much.

Dr. Cooper: Thank you very much for being with us, Dr. Draughon, and making us welcome.

There is another group with us today that I should have recognized in my opening remarks, a group that is not primarily in agriculture, that is, a group from the Army Engineers and Army Ordnance. They are interested in some of the same problems, maybe on a different end of the scale than that which interests us. We are happy to have them with us.

The first speaker on our program is well known to all of the USDA group, many of you in industry, and will be known to those of you in the Army. Dr. Smith, Dean of the School of Agriculture and Director of the Agricultural Experiment Station, received his education at A. P. I. and Iowa State College. He distinguished himself in research and teaching botany. Being in his position, you know he is a friend of agriculture, so we are particularly happy that he is here because he is a friend of agricultural engineering. He will talk with us on the role of the land-grant college in research and education. Dr. Smith.

Dr. Smith: Dr. Cooper and friends, it would be superfluous for me to attempt to add to Dr. Draughon's work of welcome to you.

THE ROLE OF THE LAND-GRANT COLLEGE IN AGRICULTURAL RESEARCH AND EDUCATION

E. V. Smith[1]

It is significant that the invitation to this conference was extended jointly by the United States Department of Agriculture and the Alabama Polytechnic Institute. It is significant that this first session is being held here in Duncan Hall, API Agricultural Extension Service headquarters. It is significant that the National Tillage Machinery Laboratory, an outstanding USDA research facility, is located on a Land-Grant College campus. Without "stealing any of the thunder" from Dr. Nichols' paper which is to follow, I should like to point out that it is significant that the problems which inspired the conception of the Tillage Laboratory were recognized by a college professor. It is significant that this seminar was designed principally for industry and that the program participants represent private organizations as well as public agencies.

[1] Dean, School of Agriculture, and Director, Agricultural Experiment Station, of the Alabama Polytechnic Institute, Auburn, Ala.

tendency for the farm machinery industry still to advertise tractors and the feed industry feeds in our agricultural student publications.

I have a son who stood the National Merit Examination this week. Consequently, I examined the pamphlet describing the National Merit Program with unusual interest. I found many companies offering scholarships in engineering, chemistry, and "science", but I found only two scholarships offered in agriculture in the entire program. It occurred to me that some agriculturally-related industries could give Agriculture a real boost by joining the National Merit Scholarship Program and offering a few merit scholarships in any of the several professional fields of agriculture. Certainly we need to keep agriculture as a profession before young people of the type who try the Merit Examinations.

We have pointed to the fact that the United States Department of Agriculture carries a goodly share of publicly supported agricultural research. They are dependent to a large extent on the Graduate Schools of the Land-Grant Colleges for the training of scientists. Industry too is calling increasingly on these same graduate schools for scientists to man their growing research and development establishments. Thus, the Land-Grant College plays a particularly strategic role in the training of future agricultural scientists at the graduate level. Here, again, we find the demand for personnel exceeding the supply. When we study the problem, we find that it goes back to the decision that is made before the boy finishes high school. Too small a percentage of the high school students who have the background and facility to master mathematics, chemistry, and fundamental biology choose a college curriculum related to agriculture; as the result, there is too small a pool of suitable college graduates for the graduate schools to attract an adequate number into advanced training. This deficiency can best be corrected through the cooperative efforts of public and private agencies.

Finally, the Land-Grant College plays another important role through the activities of the cooperative agricultural extension service. Through this arm, the Land-Grant College reaches and serves every community in the State.

Dr. Cooper: Thank you, Dr. Smith. I think that gives us a clear picture and a challenge also. We certainly appreciate that.

Next, the man that I want to present is probably better known to many of you and you have known him much longer than I have. He is a native of Ohio, but early in his career came to the South and he is an adopted Southerner now, although he went by way of the University of Delaware and was State Agronomist in Delaware. He taught agricultural engineering subjects and did research in agricultural engineering at Virginia Polytechnic Institute. He was awarded the D. Sc. from Clemson University, was here at A. P. I. as Head of the Agricultural Engineering Department from 1919 to 1936, and it was out of his research work that the idea and the National Tillage Machinery Laboratory actually got under way. From 1938 through 1953 he was Chief of the Research Division of the Soil Conservation Service, had projects all over the United States, and is known widely throughout the United States as an agriculturalist now as well as an engineer because he directed all phases of the agricultural program. Since 1953 Dr. Nichols has been director of the National Tillage Machinery Laboratory. He will tell us the purpose and history of the National Tillage Machinery Laboratory. Dr. M. L. Nichols.

Dr. Nichols: Thank you, Arthur. I enjoyed the Dean's paper very much.

PURPOSE AND HISTORY OF THE NATIONAL TILLAGE MACHINERY LABORATORY

M. L. Nichols[1]

The concept of the National Tillage Machinery Laboratory grew out of attempts to help Alabama farmers with their machinery problems. Near the end of the First World War, tractors had been distributed to farmers in many sections of the United States and their use encouraged on the basis that "food will win the war." New farm machines brought with them many problems. One of the main difficulties was traction on light sandy soils and farmers from Baldwin and Mobile counties asked the State Experiment Station for help. Since the agricultural engineers at the Alabama Agricultural Experiment Station did not know what to advise, they inaugurated a project to find out. This project developed into a rather extensive study of the relationship of wheels and lugs to soils in various conditions, including investigation of rolling resistance and the distribution of force from lugs throughout the soil.

Soil dynamics being a badly neglected field of research, there was little equipment or precedent but there was a very intense interest of the staff and the stimulating atmosphere of the revolutionary development of power farming. There were no budgeted funds for this work nor assigned personnel. We worked Saturdays and Sundays and during the week. If there was something we wanted, we made it. It was not work, we enjoyed it.

Alabama has a wide range of soil types varying from dry, light sands to very heavy tough clays, containing a large amount of montmorillonite, a mineral which swells and shrinks so excessively that the soil is extremely difficult to manage by ordinary cultivation. Much of the topography is rolling to mountains and, with the heavy rainfall of the State, soil management to till the soil and maintain erosion is a real problem. The Agricultural Engineering Department was built up around soil manipulation and erosion control.

The study of methods and procedures of soil-implement relationship research was continued for a number of years, and in 1929 Bulletin 229 of the Alabama Agricultural Experiment Station, on Methods, was published. In discussing the variation of soils it was stated "Any given soil varies from time to time in response to the various forces acting upon it. If progress is to be made in implement design, these facts must be recognized and the solution sought by the isolation of general or fundamental laws rather than by attempts at empirical measurements of unknown complexes by the so-called "practical" field trial method. Only by understanding the cause of a soil's reaction to force application can the results of any operation be accurately predetermined. Accurate knowledge of reaction to force application is, of course, the essential basis of engineering design."

Continuing the studies of wheel equipment for tractors, the work gradually was extended to cover the major aspects of soil-implement relationships. The basic work was stimulated, not hindered, by constant consideration of field problems, such as how to handle soil to prevent loss of cotton stand by crusting and the development of equipment and methods for terracing. The interest and activity in this field attracted seniors and graduate students who have carried on the program here and extended it into the neighboring states. A series of technical papers dealing with the basic soil-implement relationships were published which, after 25 or 30 years, are still being used not only in the United States but in England, Germany, France, and Italy as contributing information for advancement in the field of tillage and traction. The continued usefulness of the information gathered is evidence of the soundness of the research approach and the policy of the Institution in occupying itself with basic research as a basis for design, leaving the actual designing of equipment to the manufacturers. It was the opinion of the research worker that "cobbling up equipment" was only justified to the extent necessary for field trials of hypothesis and that can be done most effectively in cooperation with men actually engaged and experienced in the manufacturing business.

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[1] Director, National Tillage Machinery Laboratory, Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Auburn, Ala.

It is expensive to try out promising developments of design of implements in the field in full scale over a range of soils, and the Station staff felt the need of full scale trials of the implements on which they were working. They, therefore, proposed the bringing of a series of soils varying in properties into bins where they could perform experiments and studies of reaction of soils with full scale prototypes. Since the Nation at that time slumped into the great depression of '29 and the early '30's, Governor Graves felt the State should not attempt to support this project, so the Station turned to the American Farm Bureau for support. The Farm Bureau, under the leadership of E. A. O'Neal, felt this to be a real need and secured Federal support after the project was sent to S. H. McCrory through J. W. Randolph who, with I. F. Reed, was stationed at Auburn. In presenting the need of the plots to Mr. McCrory, I stated in a letter of August 1933: "I am sure that this project can be put on a sound research basis. The expense involved would enable us to obtain important results in a few years, due to the fact that we would not be obliged to wait for long periods for weather conditions to get right. Moreover, the tremendous travel cost of doing experimental work over large areas would be reduced to an absolute minimum, since the field tests required would be largely limited to the testing of completed apparatus by farmers of perfected equipment or a few check tests. It is true that there would be considerable expense involved in transportation of soil, but in the long run this investment should be less than that required for the many field trips which the workers must make to cover an area with as many soil types. Moreover, instead of occasional trips to different sections this would be equivalent to the permanent location of work on six different areas and would give the worker the advantage of studying the reactions of all of the soils of this area at the same time. Our experience with plots of this kind indicates that by careful placing of the soil in the plots, a satisfactory equilibrium is established within a reasonable period of time. While it may be stated that the conditions obtained are not exactly like any one condition in the field, it is also true that there are no two places, under natural conditions, which have exactly the same conditions, and in these plots we have obtained a sort of average or mean condition."

The representative of the Bureau of Agricultural Engineering, J. W. Randolph, was primarily interested in a project on cotton production machinery and the plots were presented by him to McCrory as a means to speed up that work rather than as basic study of soil dynamics itself. The laboratory objectives given in the request of McCrory to Secretary Wallace were as follows:

1. To determine the relation of different plow designs to their draft and action upon the furrow slice in throw, inversion, pulverization and coverage at different speeds and depths of plowing upon soils varying progressively in their constants of classifications.

2. To secure analogous data as under 1 on other soil tillage machinery, harrows, drags, rollers, cultivators, etc.

3. To study the physical effects produced upon the soil by different methods of tillage.

4. To study changes in soil tilth as affected by moisture relationships and other natural agencies to determine what will be the minimum soil manipulation necessary to obtain the maximum beneficial soil tilth for plant growth.

5. To obtain accurate measurements on the force components set up in a machine, the resulting effects produced upon the soil, and other basic information for the design and construction of new machines and modifications of existing machines.

6. To obtain wearing qualities of various metals and alloys that may be used for tillage equipment.

7. To enable thorough systematically controlled tests of machines so that those which will have longer life and which will give better service can be recommended.

8. To study under controlled soil physical conditions different methods of cotton planting so as to determine the system which will produce most favorable conditions for germination and growth during wet and dry planting seasons.

9. To check up on the popular claims that tractor wheels and other equipment produce detrimental conditions upon some soils.

10. To provide equipment whereby accelerated tests can be made with new tillage machinery.

The reasons for the establishment at Auburn were given as follows:

1. Similar work under laboratory conditions has been in progress 13 years at the Alabama Agricultural Experiment Station. Many of their findings cooperative with the Bureau of Agricultural Engineering are now ready for large scale tests with field size machinery.

2. Cooperative relationships at this Institution have been established with men who are leaders in allied fields of agronomy, mathematics, soil chemistry, and metallography.

3. Access to a large group of machinery common to the Southeast.

4. Climatic conditions are such that a full year's work can be done with a minimum cash outlay for buildings. Similar plots located in northern United States could be operated only five months each year without the addition of many thousand dollars worth of buildings.

Secretary Wallace, on the urging of Mr. E. A. O'Neal, strongly recommended the laboratory and on October 2, 1933, R. G. Tugwell requested $110,975 from H. L. Ickes, Administrator of Public Works, who allocated this money for F/P. 92 at Auburn. Dean Funchess, Director of the Experiment Station, arranged leasing of the land to the Federal Government and the contracts were let for the construction of the bins, the main building, and the main dynamometer car, and soil preparation car. The first soil was placed in the bins in November 1934. The first work on the research program consisted largely of construction of equipment and the development of testing techniques. Work was done on plows and disks and the field work on cotton production equipment was continued. Randolph was transferred, the field work finished, and R. M. Merrill from the Toledo Corn Borer Project was given the responsibility for the Tillage Machinery Laboratory. Mr. Merrill appreciated the desirability of the development of a close cooperative working relationship between the Laboratory and the Experiment Station and made considerable progress in attaining the primary objectives of the Laboratory, but the advent of the Second World War brought a demand for his services by the War Production Board and he was transferred to Washington and later left the Department of Agriculture. Mr. Reed of the Laboratory was assigned to vegetable oil work, a weak spot in the National economy, and the basic laboratory research postponed, the Laboratory being used by Ordnance for "mud crossing" experimentation. After the war Mr. Reed of the Laboratory cooperated in tillage studies with the Soil Conservation Service in developing mulching equipment, and a program of research on tires was inaugurated in cooperation with the U. S. Rubber Company. Mr. J. W. Shields represented the Company in much of this research. This project made many valuable contributions to the rapidly developing application of rubber tires for tractors and other farm implements. The services of Dr. E. G. McKibben were secured for the Laboratory in 1950. He worked on the tire studies and inaugurated a number of important improvements in the techniques of testing, one of which included the development of the cross tiller for the plots. Unfortunately for the progress of the Laboratory, Dr. McKibben was called to Washington for direction of the Agricultural Engineering program of machinery in the Department. Shortly before McKibben came to Auburn, cooperation with the Soil Physicists of the Bureau of Plant Industry, Soils, and Agricultural Engineering was inaugurated and that Agency sent Dr. Jamison to the Laboratory. Dr. Jamison carried on much research work, among which was the construction

of tension beds or ideal soil subsoils for the drainage of the soils of the plots on a plan first conceived by Kummer. In general, however, the work of the soil physicists was directed towards the study of plant-soil relationships rather than the direct soil reaction to implements. At the Laboratory the latter relationship is now being given increased emphasis.

The Laboratory at present is engaged in work classified as a "work project" called Tillage Machinery Investigations. It consists of seven line projects at Auburn.

1. Soil dynamics whose objective is to determine the physical reaction of soils to tillage tools of various designs.

2. Studies of disk blades for agricultural implements.

3. Soil compaction by machinery.

4. Subsurface tillage tools.

5. Tires and tracks for traffic and traction.

6. The effect of tillage implements, transport, and traction on physical conditions of soils.

7. Methods and equipment for measuring force distribution in soils.

There are also two projects on conservation machinery, one at Ames dealing with the development of new and improved equipment and systems of crop management for conservation in the corn belt, and one at Pendleton, Oregon, dealing with special equipment for mulch culture in the wheat growing Northwest.

The Laboratory, in cooperation with the Alabama Polytechnic Institute, has served in a small way as a training facility for Agricultural Engineering staff members and graduate students and a material increase in this activity is being considered, the Institution considering the giving of PhD degrees and the Laboratory furnishing facilities for advanced research along the lines of its authorized projects. The Laboratory staff guides the research of the student, an effective method of intensive training. This appears to be to the advantage of both Agencies as the Service needs the trained men and their production as graduate students and the Alabama Polytechnic Institute needs the use of the facilities of the Laboratory for training advanced students. The Laboratory has used effectively a few graduate students in its work to the benefit of the students, the Laboratory, and the College. Two graduate students within the past year have spent one quarter here for credit toward their PhD, one from the University of Hawaii and one from Michigan State University.

The most effective work of the Laboratory is where there is full cooperation with industry on a real farm problem. In general, the interest of the Laboratory is getting basic information on soil-implement relationship and the interest of the cooperating manufacturer is the securing of information necessary for producing better tillage or tractive machinery. The problems of soil-implement relationship are very complex. Actually, the relationship between State and Federal employees and the representatives of companies is that of specialists in different lines combining their abilities to the solution of a common problem. The problems attacked must be general problems of the farmer, not the problems peculiar to one manufacturer, so that the benefit of findings is industrywide. Both the British and German machinery industries have set up research services of this nature, the British organization is the National Institute of Agricultural Engineering at Silsoe, Bedfordshire, and the German work is at the German Agricultural Research Center at Braunschweig.

One problem of the Auburn Laboratory is to keep up with the demand for specific information in specific areas of research; for example, there is need at a number of

locations for firsthand study of local conditions to determine criteria for evaluating the need and conditions favorable for subsoiling and for field evaluation of new designs which the Laboratory research indicates to be most effective. There are many questions which are asked of the Laboratory which we have been unable to answer or even make a start towards getting the answer. It seems that to be most effective in the many problems of tillage, traffic, and traction, the Laboratory's greatest service can be achieved by its acting as a highly specialized research facility dealing with basic soil-implement relationship in cooperation with industry and other State or Federal research institutions. With the right public relationship and intelligent guidance, it can carry out research and investigations economically and efficiently on problems common to all the industry and to the farmers they serve. If American industry is to maintain its position of world leadership and progress in this field, this type of information is necessary and either the several companies must perform this service for themselves or some such agency must perform it for them. It seems logical that the most economical procedure is the getting together of the agencies concerned and interested to formulate a program to meet common needs.

Meeting turned back to Chairman.
Session adjourned for lunch.

Noon Luncheon Meeting - Thursday, October 24, 1957

Dr. A. W. Cooper presiding.

Dr. Cooper: We have Mr. Harold E. Pinches, who is an Assistant to Administrator, Agricultural Research Service, United States Department of Agriculture, to introduce our speaker.

Mr. Pinches: I find these introductions of speakers quite interesting, and sometimes one could question their value. For instance, it tells you on your program that T. C. Byerly is going to talk to you next and who he is, that he is Deputy Administrator for Production Research in the Agricultural Research Service of the Department of Agriculture, and that he's going to talk about the Importance of Basic Research to Agriculture, so any repetition of that probably would be redundant.

There are some things, however, that you may not know about Dr. Byerly. He was raised and educated in Iowa. He came to the Department of Agriculture in 1929 in the Bureau of Animal Industry. After some years in the Department of Agriculture, he spent 4 or 5 years on the staff of the University of Maryland. Then he came back to the Department of Agriculture, again in the Bureau of Animal Industry, in 1941 and has been with the Department in various, successively higher positions since that time. In the realinement of the Agricultural Research Service, which was put into effect early this year, one of the major purposes was to give emphasis to basic and pioneering research. Dr. Byerly was selected to lead in that emphasis in Agricultural Research Service Production Research, and the areas of research which are under his supervision are the 7 research divisions of Crops Research, Animal Husbandry Research, Entomology Research, Animal Disease and Parasite Research, Farm Economics Research, Soil and Water Conservation Research, and Agricultural Engineering Research. Agricultural Engineering I named last only because that is the one under which the Laboratory we are visiting today is headquartered. It is a great pleasure to introduce to you Dr. T. C. Byerly.

IMPORTANCE OF BASIC RESEARCH TO AGRICULTURE

T. C. Byerly[1]

Dr. Cooper, Dr. Nichols, gentlemen: I am at Auburn for the first time, and I can't figure out why it is the first time, since I have been in Alabama many other times. I am especially glad to be here and to get better acquainted with Dr. Nichols, whom I have known casually for quite a long time.

I would like to remark about Dr. Nichols that he worked for a period of time for R. M. Salter, and I envy him this close association. To me, Bob Salter was one of the most remarkable men it has been my priviledge to know - as a scholar, as a scientist, as an agriculturist, indeed in his whole life. Though he may never have said it, if you'd give him a few square yards of the earth's surface, he'd build land on it and grow a crop on it. That was his whole concept - not to save what we've got, but to build what we want.

While I do not think you can classify what I am about to say to you as a sermon, I shall nevertheless take a text. If I misquote the Good Book, perhaps you'll correct me. My text would be: "You have eaten of the fruit of the tree of knowledge of good and evil." Since I am no longer expected to know answers, but am expected to ask questions, I should like to follow that text with an indictment which I did not frame and to which, I suspect, you will not plead guilty, but which I think you have all thought about a bit and must think about a bit more.

You agricultural engineers - and your fellow engineers other than agricultural among you - have done these things in the last 25 or 30 years: You have added to our available cropland, for the production of food and feed crops, 75 million acres. What are we doing with it? You have robbed 3 million men and their families living on farms of a means of livelihood producing feed for the 20 million horses that would be required to pull our plows and farm machinery. You did that. I like horses. At the same time you have robbed the farmer of his flexibility, because you have not only moved these 3 millions of him off the farm and put him to work making the tractor or running the service station or being a repairman at about $2.50 an hour, whereas if he were feeding horses you would pay him only about $0.75 an hour. You've also made him vulnerable to a fuel shortage if it should happen. What are you going to run these tractors with if the oil line stops overnight? This is your problem. I phrase it in this manner because the truly magnificent accomplishments can even sometimes turn against you - the results of our research and our improvements in the production of food and technology are responsible for the agricultural mess that some folks say we're in.

When an advance in technology comes along which is tried on some farms to the improvement of the efficiency of their production, it is judged beneficial to those farmers who first adopt it and for some time along the line until a majority of farmers have adopted it. In the end it is a disadvantage, and many of them are therefore out of farming. This happens. It is not for me to say, nor for you, whether this is good or bad, but I think you'll agree that it is a matter of fact. I think it is also a matter of fact that - when you've started out to get an answer to a question - after you've found the answer, you may wonder what are its implications. I don't hold that it is your responsibility to stop work if you feel that the implications are other than those that are right and I don't believe that you could if you would. But I do believe that you ought to be conscious of those implications along with the answer itself.

My topic is basic research. I will now have to say what I think basic research is, why it is important, and how it differs from applied research. What are the requirements for basic research and how does it affect your problem? First of all, the how to do, the will it pay, the is it better, quicker, or cheaper, are words that can best describe applied research. They are important because we have to eat to live. They are going to continue to be very important.

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[1] Deputy Administrator for Farm Research, Agricultural Research Service, United States Department of Agriculture. At time of speech Farm Research was still mainly known as Production Research.

Many of the quick answers have consequences about which we are interested. I asked the waiter to leave here on the table the tray of triangular pieces of material which meet the requirements for identifying oleomargarine in the State of Alabama. It looks like butter. It tastes like butter. It spreads well. So far as I am aware, there is no chemist in the world who can tell you or tell me the chemical composition of that material. He can tell you in what way it has been modified, but his end point will be that it now has the physical consistency of butter. That's all he can tell you. He'll tell you how he did it - he did it by hydrogenating a portion of the liquid fat and mixing it with other portions until its desired physical consistency was achieved. Now I don't know whether that's important or not. It may be. It is an achievement of industrial chemistry. We presently hear a great many squawks about fats in the human diet, and it may be that you ought all be concerned with harvesting machinery and processing machinery for safflower, because safflower, amongst all of our oil seed crops, contains the highest percentage of linoleic acid. There is an hypothesis that the amount of fat ingested without harm to us depends on the proportion of linoleic acid in it. There's mighty little linoleic acid in this (oleomargarine) as it stands. It will take basic research on the metabolism of fats in the human body to determine that relationship. We don't know. It's very important to agriculture that we should know. This will require basic research in a very elegant level of physiological chemistry and biology. Most of the research on fats as related to human nutrition has been done with rats. They aren't men. It's darned hard to get a rat to get atherosclerosis or anything that looks like it. There's a problem. It's a real problem. We have this problem associated in the need for basic research with the original problem of human nutritional relationships.

Now what do I mean or understand by basic research? In common terms, basic research is addressed to why and how a process works. For example, can we, by applying physical measurements, probe the character of this material (oleomargarine) and by physical admixtures make it taste like butter and look like butter? Then, what is the chemistry of this product when we finally get through? What are the implications of all the isomers we've introduced into this material? We do know that we have made a number of things that rise from this original fat; how many, what kind, we don't know. We need that kind of research. We must have it before our job is done if we are to understand the "why."

Dr. Nichols, you have said you are growing winter oats in a particularly impervious soil in one of the tanks out there. After the rain fell on it and you poured water on it all summer and you got it saturated, you couldn't dry it out again unless you grew a crop on it. You've got all sorts of gadgets out there, and I suspect that Dr. McKibben would even get you another one if you could slice that soil up and make it over and put it back where it started from. You had to introduce a biological process in that certain way - why is that? What does the biological system do to the soil? Can you consider this tillage machinery problem without the crop that grew on it?

Now, by bringing in power tillage machinery and adding gasoline instead of horses, you also deprived the soil of a certain amount of horse manure. I expect that had some effect, too. Commercial fertilizer is easier to apply; you even get higher yields. You can know all sorts of things about the physical conditions, but still you grow a crop of oats out there in that tank. This is admission of ignorance on your part, Dr. Nichols.

Now let's take another definition of basic research. As I said to some half a dozen of you who ate supper with me last night, I sometimes use a five-pointed star to illustrate my description of research. The five points of that star would be these: Observation, comparison, analysis, discovery, and theory. From the standpoint of my definition, only <u>discovery</u> and <u>theory</u> are basic research.

Not all people will accept that. There are many people who instead would take a pyramid, and they would put observation at the bottom, saying "Let's get the facts." Then when they get a sufficient mountain of facts, and they have been sufficiently overwhelmed by all the facts that they know, they want to get an electronic computer of the most recent type - and that one won't be good enough, so they send it back and get the one that's

coming out tomorrow - to handle this mass of data that they can't handle by themselves. They would expect to mill an answer from this mountain of data. They don't even know if the answer is there.

Now, observations are necessary but they are limited in their usefulness. Many people collect data, and they record them very faithfully. We record data on streamflow, on the weather, on crop yields - on all manner of things. Sometimes these data have a limited usefulness. I love data. I love going over this historical sort of material. If you skim over them sufficiently lightly, they may not bog you down and take so much of your time you can't do anything else, and you may get a few superficial answers from them. Data are necessary, but data in themselves are only a numbers game. They aren't basic research in my concept.

From the standpoint of basic research, if you have enough knowledge of what the problem is so you can develop rational and reasonable hypotheses and can proceed to test the hypotheses with sufficient data collected under controlled conditions, as nearly as that may be achieved, then you can at least test and discard unacceptable hypotheses or retain those with which the data are compatible, so long as that is indeed the case. Most of these will reach a meaning - in time. This to me is basic research. This to me is precise and concise research.

When we are too ignorant of the problem even to develop hypotheses and to set up experiments which will collect us limited amounts of data which would test those hypotheses, we will go on gathering data and hope by milling them and comparing them and analyzing them to get the material with which to develop hypotheses. This is the hard way. But most of us are very stupid and have to go the hard way, so we keep right on doing this. But there are shorter ways, and there are people smart enough and sufficiently well grounded in basic science so that every once-in-a-while they can circumvent this entire difficult, tedious route, and do overnight what most of us can't do in a lifetime.

Now, some persons are lucky, and that is why I put <u>discovery</u> over against <u>theory</u> as a part of basic research. Persons who see something that others don't may be just lucky, or it may be that they have that spark of genius. It's a little like a gold rush; the payoff is just the same if a man works a lifetime to get it or if he simply stumped his foot, said "ouch," and thought of it. It doesn't matter; it's important. The comparison, the analysis; these things are important, these are contributory to basic research. Also, they are necessary to applied research; and applied research is necessary for solution of our immediate problems in our day-to-day existence.

In the realinement of the Agricultural Research Service, Production Research is now being renamed, Farm Research. Within the Department of Agriculture, we are recognizing Farm Research, Marketing Research, Utilization Research, Forestry Research, Home Economics Research. The farmer inside the farm gate is what we used to think about. But now most of the farmers have left the farm. I think there are about two "farmers" living off the land and serving farmers for every one who lives on the land. That, too, is important.

I went out to Walla Walla recently; I was glad to go to Walla Walla, because even from boyhood I have been interested in names of places. Walla Walla was on my boyhood list, when I was about 10, of places I wanted to go. I've been to Walla Walla and I still want to go to Timbuktu. But at Walla Walla, there is a very interesting situation. This small city has a payroll in pea packing of 7 million dollars a year. Now the peas that are packed return the farmers 2 million dollars a year. That's all right; I don't object to the price of peas, and as far as I know, the pea farmers are making a good living at it. But the very existence of that 7 million dollar payroll is dependent on the production of that 2 million dollars worth of peas.

So it is important to industry to have the problems of agriculture settled, and the problems of agricultural production settled, so that Walla Walla may have an assured supply of peas to pack. It isn't important just to those farmers growing the peas.

Potatoes would be another example. Our Utilization Research folks are developing means of making starch from potatoes and putting it into paper production. They are developing other food uses which we hope will increase the food use of potatoes. In order to have those industrial uses, you've got to have potatoes. You've got to have potatoes cheap; you've got to have potatoes abundantly, in constant supply and of a suitable quality. Those are production problems. You can't have industrial utilization of nothing, or of a surplus that's a one-shot deal. No industry can be built on a one-shot deal.

So, we're not prepared to sell production research short. But - yesterday evening, I was shown a very fine farm used for demonstration and development purposes by the Alabama Polytechnic Institute Department of Agricultural Engineering. I saw cotton on that farm that was said to yield two bales to the acre, and I asked what the yield was before they fixed it up. They said it had been abandoned; but if it had been worked, it wouldn't have produced a quarter of a bale. That's an achievement. Do we need the two bales of cotton? I don't know. What I'm saying is that we must each of us face the consequences of the things we do and take them into account. The base consequence is this: Somewhere along the line, the aggregate advantage of all farmers seems not to be the same as the advantage of some individual farmers. Shall we say to the individual farmer, "Do these things, which will increase your efficiency, will increase your output per man-hour input or per dollar input. This will be to your advantage." And it will. And then when enough of them have acted on this good advice, this suddenly becomes bad advice. That's a paradox to which I do not know the answer, nor do I know of anyone who does know the answer.

The answer is very important to all of you, and you are very intimately concerned with the solution of this problem. You are intimately concerned with it in the application of your machines and in the development of new machines. I am told that your machines break too frequently. Say a man has invested a few thousand dollars in a combine. It's out in the middle of a wheatfield, and it's a nice sunny day and he's about to get his wheat cut, but it breaks down and he won't get a repair part until next Sunday; by that time it's raining. He's lost all that time, and this annoys him. This, I think, is a problem. I think it may involve basic research to solve it, because machines have been breaking a long time. I know that when I was a boy on the farm in Iowa we used to find a great deal of use for a pair of pliers and a piece of baling wire. Some of your machines have grown so heavy and complex that baling wire seems not to have the tenacity it had in those days. That's too bad.

Another thing is this; you build a machine to do a job. You say in order to be efficient, it has to be a certain size; and you have to build so many of them, else you can't tool up the factory to build the machine. Well, what do you do with a crop in which there are only a dozen machines needed? There are such crops. There are small crops that would be profitable if grown but that have a limited market. Who will make machines for them? The blacksmith? Where is he? Around the racetracks there are still a few, I believe, but for the most part you have to hunt for a blacksmith. There is a need for many small machines.

Another thing I wonder about - I'm no engineer, I can only ask questions - is this: We have been rather startled in the last few days, and in the last few years, by the opening of new realms of knowledge which we have attributed to a few scholars, mathematical computors, and electronics. As far as I know, Dr. McKibben, Dr. Nichols, Mr. Pinches, Dr. Carleton, the beginning of all of this is not a four-letter word, but something with just four letters in it, $E = MC^2$. That sounds simple. It may take as much hard work to simplify your machines and as much genius as it did to develop that simple equation, but I think that's what you've got to shoot for.

From the standpoint of training scientists, and of using them, we have to recognize the question that is being put before us this morning: Why aren't our boys going into agricultural colleges in proportionate numbers? But proportion to what? The agricultural population dropped between April 1, 1956, and April 1, 1957, by 1,800,000 people. There are, on our farms, about 135 young men coming to work for every hundred openings.

Would you expect, therefore, agricultural colleges to be training people for purely agricultural things, i.e., for farming? Or, shall we have to learn to say that farming still involves 40 percent of our population to supply us with food and clothing, to develop, and process, and serve us with the products of the land? Now there are two points which I would like to make with you. First, I am advised that in the past few months, the proportionate numbers reversed themselves, and we now have more people working in services than we have in the production of goods. To me, the ultimate conclusion of this trend would be that sooner or later we shall veto the old copybook maxim that we can't live by taking in one another's washing, and proceed to show that we can. That's one of my points.

The other point is that the agricultural colleges will modify - and they can't modify unless you give them the means to do it - their curricula and their attraction to boys, will conform with what will give them incentive and opportunity, or these colleges will continue to decline and, perhaps, pass out of existence.

What does it take for a young man to compete at the highest level in the United States today? They are rather simple things, because any research worker - and I defy you to add to my list - can do only these things, besides think. He can measure, he can count, and he can weigh. Those are simple tools. So I say to you it is becoming increasingly important that our students be offered substantial basic training in language, in logic, in mathematics, in physics, in biology, and in chemistry. They must have these things, if they are to be useful to us. Those of us who have to recruit people will look for persons who have these types of training, wherever they may be needed. This we must do.

As far as research is concerned, there is a necessity for teamwork among people of different skills. This is especially important with respect to applied research. It is sometimes true with respect to basic research; but in basic research there pretty nearly has to be one man who does the thinking - one man who carries the ball and calls the tune - and the others would be his helpers. We must have people who will think, who have the capacity for doing research, and these people must be set out and given the opportunity to do basic research; a few of them to do pioneering research - to follow something into the unknown. And those people who both will and can, and prefer - as many do - to collect data, to compare, and to analyze, must then be content to work in teams to apply themselves to problems, for which the reward may be, and often is, greater than the reward for doing basic research, or for doing pioneering research, which is the least tranquil one.

But another thing we must have. We must have more incentive, more recognition, more honor to our people who have succeeded in research, if people are to be attracted to research. Dr. Nichols, all honor to you.

Dr. Cooper: Thank you Dr. Byerly. You can tell from that hearty applause that we all recognize those words of wisdom, and we will ponder them, and they will do good.

1:30 to 4:30 p.m., October 24, 1957

TOUR OF NATIONAL TILLAGE MACHINERY LABORATORY

Typical equipment and test arrangements were demonstrated on the Laboratory plots to show the versatility and exactness of the full-scale test equipment for studies of tillage, transport, and traction equipment under varying soil conditions. The equipment demonstrated showed both the methods of measuring and recording reaction to the test tool, in or on the soil. After the demonstration on the plots, the visitors were divided into four groups to facilitate handling in the control laboratories where available equipment and procedures used were discussed by the staff personnel.

6:30 p. m. Banquet Meeting, October 24, 1957

Master of Ceremonies, F. A. Kummer, Head, Agricultural Engineering Department, A. P. I. [No speeches.]

Friday Morning, October 25, 1957, Duncan Hall

Dr. M. L. Nichols, Chairman

Dr. Nichols: This morning, we come to what most of us have looked forward to as the part of the program in which we would commence to get the plans for the future in a tangible shape. I am hoping that, when this is over, the ideas of the group will be sufficiently clear to incorporate into a longtime program. As most of you know, we have had quite a reorganization in the Federal Government in the last few years, in part of which it was my pleasure to participate. As you study these changes, you find that what usually occurs is that some people appear to get bigger and some to get smaller. You notice quite a growth in stature of certain people. Today we are very fortunate in having with us one of the young men who, by his growth, from my point of view, gives me a great deal of encouragement as to where the Department is going in the future. The gentleman is a native of Nebraska, at least he went to school there, and later went to Iowa. He told one of the men the other day that he slept through a course in soils and thought that he learned so little about it that he went back and took it over and then found out that he was a specialist. I think that is a little exaggeration, but it still is a good story. Without any further talk, I would like to introduce Dr. W. H. Allaway, Assistant Director of the research division of Soil and Water Conservation in the Washington office. He will talk to us on the very broad subject--he can say almost anything he wants to--of "Tillage and Crops."

Dr. Allaway: Thank you Dr. Nichols. It certainly is a real pleasure to be here and I wish that I could have been here for the proceedings yesterday.

TILLAGE AND CROPS

W. H. Allaway[1]

When engineers and soil scientists get together to talk about tillage, the engineers usually make the request "If you soils people will just tell us what you want, or better still what the plant wants, in the way of a seedbed and rootbed, then we can go to work to design a machine to produce the condition--whatever it may be."

The soil scientist usually comes back with either no answer, or with different answers from different people, or most frequently the statement that the best kind of seedbed and rootbed depends on so many different factors that one cannot specify a best condition for all kinds of soils and weather conditions.

Actually, the situation is not nearly so bad as the impression an outsider might get from sitting in on a session where tillage research is being planned. After all, we do grow crops--at times even too much of some crops.

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[1] Acting Assistant Director, Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

We know, for given plants, a great deal about desirable ranges of moisture, salt content, nutrient level, temperature, etc. We know that surface crusts are generally undesirable, and yet the soil must be firmed sufficiently to provide good contact around the seed.

Perhaps our difficulties in planning tillage research stem more from a lack of putting together what we do know--than from a lack of information about details. This morning I should like to examine with you some of the possibilities for developing and using a unified theory of plant-soil-tillage relationships.

To start with, let's try to write an equation expressing the rate of plant growth. To simplify the situation, we shall assume that all genetic characteristics of the plant, and all the above-ground factors of the environment are held constant. Now this is holding a lot of factors constant, but even so the equation will be complicated. Soil factors that effect plants include the moisture supply, aeration, temperature, nutrient supply, mechanical resistance, toxic substances and others, some of which are no doubt still unknown. Each of the factors listed has its own set of components. Nutrient supply, for example, is made up of the amount of each nutrient at the root surface at any one time, plus all the factors controlling the rate of renewal of these amounts plus the interaction between the nutrients, to mention only a few. The relative importance of these different components is not known, but we do know that this relative importance varies with different values of the other variables in the equation. So the rate of plant growth on soil is some function of many factors, with each factor having significant internal components. The first approximation to such an equation might look like the following:

With constant genetic characteristics, stage of growth, aerial environment
Plant Growth Rate = F (soil moisture, temperature, nutrient supply, aeration, . . etc.).

Some of the factors are undoubtedly still unknown to us.

But there is a serious defect in this equation. The factors listed on the right-hand side of the equation are not independent variables. Soil aeration is dependent upon moisture content, certain aspects of nutrient supply upon moisture, aeration and temperature, and so on. Unfortunately, we cannot, at this time, accurately define, for all cases, just how the variables depend on one another and thus eliminate terms from the right-hand side of the equation. Furthermore, the factors may interact with one another in their effect on plants. The optimum temperature for plant growth may depend on the nutrient supply, etc.

In view of the complications apparent in the oversimplified equation it is to be expected that our ideas of the ideal seedbed or rootbed will be pretty vague.

I do not wish to depreciate in any way our knowledge in this field. Certainly, we have come a long way from the days of van Helmont's classic experiments on the growth requirements of plants, and the current rate of progress is encouraging.

Recent years have seen important scientific breakthroughs in our understanding of the processes through which plant roots accumulate nutrients from soils and nutrient solutions. Basic principles governing the role of nutrient concentration, competing ions and oxygen supply are becoming established. If we define certain of the other conditions, we can in many cases determine the relative level of adequacy of some plant nutrients by chemical tests of the soil.

In the case of moisture, we can describe the situation in soils in terms of the amount of water in the soil and the force with which this water is held by the solid phase. Notable progress in determining the rate of movement in soil water in unsaturated soils has recently been made at the U. S. Salinity Laboratory. It appears that the rate of movement of water in unsaturated soil is an exponential function of the moisture tension or suction in the soil.

And so, in spite of the difficulty of the problem, we can approach our tillage research problems with reasonable confidence that we have, and are still expanding, a background of fundamental principles to use in further research effort.

Now--what directions can we take in these efforts?

First of all, I should like to point out that we will not make progress by minimizing or failing to recognize the complexity of the relationships between plant and soil and between soil and tillage machines. Too often in the past I think we have failed to realize that desirable results obtained with a given implement or practice on one soil may be useless or even harmful under other conditions. Perhaps one of the classic and most costly mistakes of this kind was made when the homesteaders took moldboard plows, which had been so successful in the Central States, to the driest parts of the Great Plains. Engineers and soil scientists working on tillage problems must appreciate the complexity of the system with which they are working, measure and report as many of the characteristics of the system as can practically be done, and strive for an understanding of just how their applied treatments change the condition of the system. This is essential if other workers, with different conditions, are to make the most effective use of research reports.

The problem of how best to measure the factors that control plant growth in soils, and the effect of tillage treatments on these factors, will need continuing attention. We know that aeration conditions in the soil are important and that different tillage treatments bring about variations in soil aeration that are reflected in plant growth. Yet we cannot claim to have a satisfactory measurement of the aeration conditions at the root surface. Surely we can hope for progress in this direction if we combine the best thinking of people from different fields--plant physiology, soils, chemistry, electronics, and engineering.

These measurements of factors affecting plant growth in soils should be followed by better determinations of critical limits for each factor. Within what range of values is each factor effective in controlling plant growth? How are the critical limits for one factor affected by the values of other factors? This information may make it possible to design experiments where certain factors are restricted to values above the critical limits, and thus effectively eliminate them from the equation. This is, of course, an old trick--but I think we are sometimes fooled into thinking that a given factor is present at an overabundant and nonlimiting value when this has not actually been the case. A better understanding of critical limits could have prevented this.

We must also be alert to recognize additional soil factors that may affect plant growth. I think it would be a very rash statement to say that we know all the factors and what we need is to be able to measure and control them. I would prefer to be quoted as saying that we don't yet recognize all of the soil factors that may control plant growth, and that important new characteristics of the root environment will surely be discovered. Many of you are aware of experiments where an attempt to measure the effects of some practice--fertilizer, tillage, or irrigation--on plant growth has been attempted, but failed because the growth of the plants was really controlled by the nematode population in the soil rather than by the applied treatments. To me this means that our tillage research workers will need to maintain contacts with a wide circle of other scientists, and be quick to consider new findings that must be taken into account in designing tillage experiments. Possibly some new scientific disciplines will need to be represented on tillage research teams.

The work being done here at the Tillage Laboratory on the effects of machines on soil conditions represents another phase of tillage research essential to continuing progress. Results from this kind of work are required if we are to make use of what we know about the relationship of soil properties and conditions to plant growth. An understanding of mechanisms by which different implements change different conditions in different soils will not be easy to obtain, as the staff here well knows. The nature and magnitude of the forces among individual soil particles is a difficult research field in itself. When we

superimpose upon this problem the problem of how fuel energy can be converted to forces that will either overcome or augment these physicochemical forces in the soil the difficulties are evident. The most reassuring part of this picture is the realization that here at the Tillage Laboratory the problem is clearly recognized, and the staff includes the types of competence essential to a basic attack on the problem.

We can point to some outstanding examples of successful application of the team approach to tillage problems. Cooperation between agronomist and engineer has certainly helped in developing better methods and machinery for fertilizer placement. Another good example of productive teamwork comes from the research done in the Imperial Valley and at the Salinity Laboratory on planting procedures for salty lands. In the problem, plant physiologists contributed their work on the salt tolerance of seedling plants, soil scientists contributed principles of movement of salts and water in soils, and the engineers developed machines that shaped the planting bed and placed the seed in positions away from the zones of high salt concentration.

In summary, I feel that our future tillage research should address itself to two main questions. First, how do soil properties and soil conditions affect plant growth and, second, how do machines change conditions in different soils? Workers in each of these fields must keep up with the things being done in the other. In each field basic research is the primary need. The relationship of soil conditions to plant growth will need to be studied under closely controlled conditions, where the equation which I attempted earlier can be simplified as much as possible. Some of the experimental setups will not have any resemblance to a crop field. The little cells filled with glass beads used by Dr. Gill in his work on mechanical impedance are an example of the kind of research technique necessary. Above all, we must define our seedbed and rootbed conditions in terms of measurable properties of the system itself, and not in terms of the machines used to create these properties. Bulk density, moisture content, temperature, etc. are proper variables in this sort of research. Comparisons of plowing and disking, without measurement or reference to the nature of the soil conditions produced by each implement, are not likely to be very useful.

In studying the effect of machines on soil, we will need to know the distribution of forces on and around simple metallic shapes as these shapes move through different soils at different rates and moisture contents. Experimental setups that permit an accurate picture of the energy transformations taking place will be needed. The resemblance between these experimental setups and actual tillage machines is of secondary importance. Engineers in Industry can translate these basic findings into implement design.

If sufficient effort can be directed toward basic research along these lines, by individual workers and research teams of people who recognize the complexity of the whole field of plant-soil-machine relationships, future years can see important progress in the field.

Dr. Nichols: That certainly was a very fine paper, Dr. Allaway. I followed it as closely as I could, but you had so much in that paper that I am rather anxious to get a copy of it and study it. The things you discussed are subjects of great interest to this group. The work you have been doing on tillage and crop yields all over the United States is taking effect. Dr. Allaway is leading that work for the Soil and Water Conservation Group. Are there any questions that you would like to ask Dr. Allaway? I expect that most of you are like I am, and would want to think about that a little.

Now we come to what in my mind is one of the most important parts of the program, which we hope will lead into an extension of the whole field of tillage research by better inter-relationship between our Federal and State Institutions and industry. We have, to lead this panel, another man from the general high-wind area out there in Kansas and Nebraska. When I went to grade school, that area was called the "great American desert," but they sure have made that area bloom since. I don't know that I need to say very much to introduce Dr. Carleton. You all know him. The work that he did in getting

his Doctor's Degree and his direction of the Agricultural Engineering Research at Michigan State University stands out for itself. So, without further ado, I want to ask Dr. Carleton, Assistant Director, Agricultural Engineering Research Division, Agricultural Research Service, to introduce his panel.

PANEL ON EQUIPMENT AND SOIL RELATIONS RESEARCH NEEDS, Leader W. M. Carleton[1]

Dr. Carleton: Thank you, Dr. Nichols. Before we get into this panel, I'd like to make sure that each of you is equipped with an essential item for participation in the panel - a pencil. The way we propose to handle the panel discussion is that we will first have a formal statement by each one of the panel members, including also Dr. Allaway. And then we will have questions.

In order to prime the pump a little, it might be well if we were to review some of the things on which questions might be asked later. I feel this may be done by reviewing very briefly some of the problems which have been pointed up by people in the past, with the idea that, as the panel members make their presentations, we could use them to serve as innoculants for the questions that we hope will come out of the discussions.

Important problems include soil physical conditions (we've been talking about that), seedling emergence, cropping systems (and of course that leads quickly to tillage implements) which produce and maintain desirable soil physical conditions, methods of measuring soil physical conditions, tillage and its relationship to soil conditions, and soil moisture storage and its relation to tillage. Other problems relate to wind erosion, methods and equipment for summer fallowing, minimum tillage, causes of formation of compacted zones, method of placement of residue, methods of correcting compacted soil conditions, tillage methods and cropping system combination, subsoiler types, basic studies to determine physical and chemical processes in soil compaction, soil moisture, soil stress and implement weight and forces, implement traffic and seedbed preparation versus compaction, and, perhaps, even methods for overcoming compaction. We have been discussing items of tillage and tillage equipment and how we do tillage for the past 2 days. Then Dr. Allaway comes along and puts an equation on the board which includes all the things about which we have been talking. Now if you will please hold your pencil in readiness so that you can jot down ideas during each speaker's presentation, we will take up the questions after the formal presentation.

According to your program, you have four parts in the panel on equipment and soil relations research needs; tillage equipment, traction, transport, and trafficability. The first item will be discussed by Mr. Carroll Mullen. Mr. Mullen graduated from Mississippi State. He spent 5 years in the Army piloting airplanes, got out of the service and went back into personnel work and sales work and sales manager, and then was promoted to president. It speaks well for agricultural engineering possibilities - we ought to mention that to the students, and now the first member on the panel, Mr. Mullen, who will discuss tillage equipment. Mr. Mullen.

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TILLAGE EQUIPMENT

C. C. Mullen[1]

Good morning, gentlemen. About the only research I have been able to do on this is that I found out that there are about 4,700,632 people who know more about the subject that was assigned to me. But in talking to a few of them, I find that very few of them are any more confused than I am, so I think I can shed about as much light on what we don't know as any of you. All I know is what I have seen, heard, or read. When I sum that up--if you think back over the things you've seen, heard from various sources, and read, you find probably that you're not the only confused individual. There are many theories. Most of us, when it boils down, are confused by facts. Simple facts, or at least what we think are facts. This is one thing that I heard about 10 years ago that stuck in my craw. Too often, most of us strike on a theory and we set out to prove that theory--our theory--is correct. And then we get all the facts--all the facts we want. But we don't get all the facts, and gentlemen, there is a difference--there's a big difference. After we seize on all of those facts to back up the theory, we are pretty well set. Then, before we get all the facts, we go out, we talk that theory, we publish it. Then we wonder why the farmer gets so confused. Now for a few words on the tillage practices I have been most closely associated with for the last 10 years. They are the simplest of tillage practices. However, I think I will be able to show you that we don't know too much about them. These practices are deep tillage and harrowing. There is a lot we don't know about them, today. I believe that there are the only two tillage practices necessary for successful farming in 99 percent of the crop area of the world. I actually believe that. It's easy for you to see how I arrived at that fact--that's the only tillage equipment that we manufacture. That might be a little facetious; however, that's the way most other people have arrived at their facts. There again, I have--or think I have--all of the facts I want. But do I have all of the facts?

Now gentlemen, let me explain why I think we have been, and probably still are, confused in this tillage game. Is deep tillage new? No. This practice was in effect and actively practiced, to my knowledge, more than 40 years ago on the West Coast. There was a need for it. They designed these--shall we call them crude?--implements. Let's call them crude, because they must have been--that was more than 40 years ago. Gentlemen, I submit that Mr. Killifer's first subsoiler standard was curved--the first one. He saw that it would require less power if he curved those subsoiler standards. However, Dr. Cooper told us yesterday that a curved section standard to do the same amount of work as a straight standard, required 10 to 25 percent less horsepower-draft requirement. He has proven that down in the lab. How many of you realize that more than 90 percent of the subsoiler standards being sold, available to and being delivered to farmers today, are straight subsoiler standards? That's true. As an example, the John Deere - Killifer still makes both types subsoiler standards. However, more than 90 percent of their sales are in the straight subsoiler standards. There is one little area down in Mexico that hasn't changed for 40 years. We think they are mighty backward, but they still use only the curved subsoiler standard. Now, gentlemen, that's significant. When I tried to find out why we have done that, I've been completely stymied. I did do my best for about 90 days after I seemed to strike up on this gem, to find out why some people at one time built curved subsoiler standards and then changed to straight. I think the best answer I got - from the only one who knew really why he changed it - is that in a small subsoiler standard for a wheel type tractor, it cost 80 cents less to make the straight standard than it did the curved standard. Now, in selling price to the farmer, that probably amounted to about $3.00. But in this competitive market that we have, $3.00 a standard is important - important enough to cost that farmer 10 to 25 percent more fuel, more wear and tear on his tractor, to pull that thing through the ground. In other words, we not only made him pay for that saving, we are going to make him pay for it as long as that implement lasts. Forty years ago those standards were far harder to make than they are today, yet they curved them back then. Now gentlemen, again I say, that's progress,

[1] President, Rome Plow Company, Cedartown, Ga.

and I'm afraid we can measure some of our other progress in our tillage practices by the same backward yardstick. I think that's the only thing that we can call it.

Now I'm going to undertake to enlighten you on another subject that we're familiar with, and that is disk blades. I am going to preface these remarks by the fact that we now have four different concavities in a 24-inch blade. Why? Nobody seems to know why. In the Florida area, they feel that they have to have a shallow concavity. When you get up into Georgia and the Carolinas, they want a deep concavity. You skip over into Mississippi, and they want a shallow concavity. You hit Stuttgart, Arkansas, and go north of town and they want a shallow concavity; south of town they want the deep concavity. That's no exaggeration. As we go west, they want a shallow concavity--why? Because they get clogging. Their soils are wet--they are working the soils wetter now than they used to. Now, after listening to Dr. Cooper yesterday, I don't know which is going to give them the most compaction. We do know that a "dish" is probably going to cause more side pressure. However, as you "narrow-up" or "shallow-up" the concavity, you are putting all of that weight on one point. His work here has proven that we get the same amount of compaction, we just get it deeper. But nobody seems to want to think of compaction, we just get it deeper. But nobody seems to want to think about that. You tell these farmers that they are plowing the soil--or that you feel that they are plowing it--too wet, and they will say that, well you get that theory because your disk blades are too deep and they won't shed the soil. As I say, there has been a lot of deep thinking going on in this field.

Now again--several years ago, we were asked to see if we could standardize on disk blade diameters, concavities, the number of notches in the cut-out disks, and degree to which edges were sharpened. Again, standardization, just like these straight subsoiler standards. In the last 12 months, the English have standardized on disk blades. They want to make sure now that when we ship the latest type disk blades into these foreign countries and they ship also into that market, that the disk blades are interchangeable. Again, with no thought whatsoever as to the work they are going to do. They just want to make sure that the farmer can get them - that seems to be the main thing. I started asking questions several years ago on that basis, and it boiled down to the fact that we have no actual basis for our disk blade specifications. On asking a few other harrow manufacturers, many of whom had been in the game much longer than we, I found that theyhad no better basis than we had. It was a simple rule of thumb. Yet those rules of thumb had been transmitted in to the disk blade manufacturers. That's what the manufacturers have made, and we accept that as gospel. Again, rules of thumb, gentlemen, and that's what all too often has regulated--you might say--our progress in agriculture. No particular reason. It worked for one man, so that should be gospel. There are hundreds of thousands, probably millions, of disk blades sold every year. I dare say that there is nosegment of our tillage tool industry where we have fewer facts to go on. I am afraid, and I'm beginning to strongly suspect that Mr. McCreery in his work over there on these disk blades--concavity and what have you--might prove to us that we have been wasting 10 to 25 percent of our horsepower when we pull these disk blades through the ground.

One other thought. I don't know that we have made too much progress in any other tillage implement--that is, the implement itself. Sure, instead of pulling 3 feet of it with a mule, we pull 100 feet of it with, say, 300 mule-power. But, in the last year, we have received some old prints that were taken out of books that have been salvaged in Europe. These prints are sworn to be authentic, and I have no reason to doubt that they are. Some of those prints are dated 1820, 1830, and one says circa (about) 1790. The best we can tell, some of these practices were in Germany, some of them were in England, and the other--we feel certain--was in France. We have looked at these farming equipment pictures. They had the same tillage tools then that we have today--almost exactly. They were plowing with wooden moldboard plows, but I understand that this bent beam came in later on somewhere. However, I guess he had a crooked limb, because the beam was actually bent. Now, for his harrows--he had a spike tooth section harrow. They were wooden spikes. I guess they had hickory or very hard wood. The seeder was pushed by a woman. It had a wheel on it. It had two handles coming back, and it had a seedbox. It also had an articulated lever up there, shall we say, that regulated the dropping of the seed. Their culti-packer seemed to be a log with two stub axles stuck in the ends of it.

But that log was banded with ribs--I couldn't tell whether they were metal or wood - but it was doing just about the same job of culti-packing that we are doing today. In the latest picture, the one dated 1830, now that's pretty recent, it's only about 120 to 130 years ago--they had a spring tooth cultivator, very similar to one that I saw in front of a hardware store on the way down here. Again, gentlemen, we've made a lot of progress. Today we make them out of iron, and that's about the only thing we have changed. We put bearings in them--a little improved bearing takes a little less horsepower. But I submit that we are doing the same job that they did then.

Now, you ask me what equipment and soils-relations-research needs for tillage tools are required, and I submit that any basic fact--I think we know all too few - any basic fact about tillage that we may learn today will be one more basic fact than we know tomorrow. And I believe that you folks here at Auburn are ahead of industry--that might be an unfair statement, but I know you are way ahead of us--in our mutual search for all the facts. Not just the facts that you want, I think you will be fairer than that, and you are trying to get all of the facts about every particular item that you test or check. I think it behooves all of us to pool our research resources and facilities--let's say with Auburn--to obtain the research data so vitally important and necessary if we are to make the progress in tillage tools and practices we think is indicated. Then, after pinning down these basic facts, they must be conveyed to the farmer--the user--in language that can be universally understood, instead of advertising bla-bla and doubletalk. I dare say that no segment of the buying public has been any more subjected to propaganda than the farmer has. Again, the same old tools. We have changed, maybe, the paint job or something like that and it's an entirely new tool. They are getting a little bit smarter--I say getting smarter, but they have always been smarter than we thought they were--and I don't think we are going to fool them much longer. As an example, there is a very successful man in our home town. He is an engineer. I won't say that he graduated from Auburn, because I'am not sure. However, he was very successful in mining, then in contracting, and, as he was raised on a farm, he went back to farming. Here, we are getting away from cotton. We have had to go to small grains and dairy. Everybody had jumped into poultry, and that was kind of tapering off by the time that Sam got ready to go into dairying. So he built his barn--to all the specifications that he was able to get. They say that an inspector came around, checked his barn, then said, "Sam, I think that everything is in order except that you have forgotten a toilet." For a class A barn, you must have a toilet. As I say, this was an intelligent man, but the way it was put to him, he scratched his head. And then he said, "All Right, sir, I'll put in the toilet. But I'll bet you a five dollar bill right now that I ain't got a cow in the herd that is going to use it." Too many things have been put to them, and they don't understand any more about it than he did.

To me, the most pressing need that we have today (not to take exception to Dr. Allaway) is the proper seedbed or root zone preparation; that is, based on what limited knowledge we might have today. It might take us years and years--it looks like a lot of time is indicated--before we have all the answers we are looking for. There are two things that I am very much confused about, and I find in practically every area that I go into that they are very much confused. One is the best treatment of weed seed. Again, a gentleman who spent about 20 years in research once told me, "Whatever you do, don't turn those weed seed under." There are many people advertising today that the best way to control your weeds is to turn them under deep. Their research, dating back as I say 20, 30, maybe even 40 years ago, proved to them that the only place they could handle the weed seed was on the surface. There, and only there. If they buried it, they are not going to kill that seed. It would just be there to haunt them when they turned it back up to the surface. Yet I am afraid that many of our farmers--probably many of our agriculturalists--in many areas are forgetting that once they turn them down, one of these days they will turn them back up, and very few of them are going to be dead. Then, I guess, we will try to get them back on the surface so we can get at them.

The other thing is the moisture relationship to the soil when the soil is tilled. There is a definite reason why most of these soils--and again let's say the Mississippi Delta--but I submit that it probably is true in 90 percent of our area today. It used to be that if

it rained, all right. So what? He had plenty of mules and plenty of labor, and if he needed more he could pick them up at two-bits a day, so he just waited until the soil was at the optimum condition (or so he thought) before he plowed and prepared that soil. Today, that labor is gone, and the farmer is limited by the amount of equipment that he can use to do the job. He is also limited on the length of time. Therefore, in many areas today, wet or dry, they don't care. They go on out there and prepare the soil the best that they can and they plant. They have been getting some pretty fair crops. However, again I wonder if they continue to do that, how long is it going to be before these practices return to haunt them?

Now, gentlemen, I hope that you are no more confused than I am, because that would be pretty confused. Thank you very much.

Dr. Carleton: Thank you Mr. Mullen. I think by now you should have enough ideas to have at least two questions written down on each of your respective note pads.

The next man on our panel here will talk on traction. Mr. W. H. Worthington, Director of Research for the John Deere Engineering and Research Center of Deere at Waterloo, is a man for whom I hold a great deal of admiration. I have been following some of his writings in research for quite a long time. He is a past president of the American Society of Agricultural Engineers, he is the recipient of one of the ASAE gold medals which are awarded annually, and he has written to considerable extent on some very technical items, particularly on tractor research. Mr. Worthington has quite a varied background. It used to be that he spent his time commuting between Russia, Brazil, and Argentina when he worked for the J. I. Case Co. This is commuting on a rather large scale. As you can see he has traveled considerably. He has had a lot of experience with different companies--the Case Company, Altman-Taylor, Electric Wheel, Rumely, Gleaner, --and with Deere since 1930. That is enough of the background of the man who is to discuss briefly with us the subject of traction. Mr. Worthington.

TRACTION

Wayne H. Worthington[1]

Dr. Carleton, Staff of the USDA Tillage Machinery Laboratory, and Fellow Engineers.

Our meeting here today may well be compared to the commencement exercises at a university, except that for the graduates we are honoring the facilities, personnel, and staff of the USDA Tillage Laboratory. Like the scholar who graduates "magna cum laude," this facility has made great progress. It is firmly established, well prepared for the jobs of the immediate future and for the long term ahead, and has substantial backing. Nevertheless, the time is appropriate to examine the problems ahead, and ask ourselves, "quo vadis."

Carrying the simile a step further, the situation is comparable to that of a traveler about to purchase a ticket at the railroad station. He is all packed up, and ready to go places. But two approaches are now possible. The first consists of walking up to the ticket office, laying his money on the counter, and calling for a ticket to a specific destination. The transaction is simple and our traveler is promptly on his way. Now let us consider the second hypothetical traveler, the man whose objectives are a bit fuzzy. He walks up to the ticket window, lays his money on the counter and asks for a ticket. The

[1] Director of Research, John Deere Research and Engineering Center of Deere Manufacturing Company, Waterloo, Iowa.

agent inquires, "Where to?" Comes the reply, "I dunno, what tickets you got." Absurd though it seems, the point is our traveler can go from where he is to any destination in the world, provided he knows where he's going.

If we of the farm equipment industry can state our problems, outline to the Staff of the Laboratory how their work can best assist us to make better equipment for the American farmer, and make our experience available as they see fit to use it, we can be helpful in making their efforts fruitful. Laboratory findings per se never make two blades of grass grow where but one grew before. They must be properly interpreted and applied. We who build tractors and tillage machinery are the "middlemen," as it were, who can apply the findings of the Tillage Laboratory to the design and development of new and improved equipment for the American farm scene.

At this point, it should be emphasized that the Tillage Laboratory should never devote its efforts to the solution of problems which the individual manufacturer should do for himself. Rather, their facilities and unique talents should be utilized in the broad areas of basic research, to develop knowledge which can be utilized by all. And it will inevitably follow that the benefits accruing to each of us will generally be in proportion to the extent of our individual cooperation and contributions.

Personally, I am ambitious for the Laboratory. I would like to see it enjoy the prestige of the British Institute for Agricultural Engineering at Silsoe and the German Agricultural Engineering Research Center at Braunschweig. Ably directed and staffed, and properly supported, all this is readily possible. But until recently, we of the farm equipment industry did not face up to our responsibilities of supporting this work.

In spite of the great contributions made by the Laboratory in regard to exploring tractor tire performance and tire and soil relationships, a significant segment of those concerned not only disregarded these findings, but chose to cast reflections upon the entire effort. Happily, some three and a half years ago, a cooperative engineering effort was undertaken by tractor and tire engineers and the Laboratory, working through the SAE Tractor Tire Committee, which accomplished two significant objectives:

1. The development of low-section-height drive-wheel tires, which greatly benefited the larger general-purpose tractor. This effort has received international recognition.

2. Verified many of the published findings of the Laboratory. In this way, a background of many years of work was added to the more recent findings resulting from the SAE Committee's work.

The revolution in American farming during the past two decades - a feat unequaled anywhere else in the world - results largely from the large-scale application of power farming practices. Much of a tractor's power is delivered through its drawbar, or hitch, to the implements, and, in turn, is dependent upon what is generally termed "traction." For purposes of discussion, traction may be thought of as the dynamic relationship of tractor tires, or tracks, and soil. In spite of the fact that there are now some 4.5 million tractors on American farms, far too little is known of the factors which combine to provide effective and efficient traction, and the effects on the soil resulting from the action of tractor tires and tracks in passing over the fields.

There are many ways in which the Laboratory could be of assistance in the development of better tractors, as follows:

1. Extend existing knowledge in areas including soil physics, soil dynamics, tire-soil relations, and related soil-and plant-root relationships.

2. Develop definite facts regarding the nature and effects of the many variables involved.

3. Improve field testing and reporting practices, including better instrumentation.

4. Make available, by the publication of entire reports, summaries, and bibliographies, the results of work in this general area by foreign research groups. Much of this information would involve translation of articles published in languages other than English.

5. Set up definitions of terms now loosely applied. As examples, we speak of the "rolling radius" of a tire as though it were constant, when actually, due to transient variations in draft, loading and lug deflection, and penetration, variations on the order of 3/4 inch to 1 inch continually occur. When plowing to a "uniform depth," is reference made to regular, level furrow bottoms, lying in a common plane (regardless of surface irregularities) or to furrows which closely follow surface irregularities?

6. Consideration of the many variables involved in both implement and tractor performance shows that many are of a statistical rather than absolute nature. From this, it may be fairly concluded that results may be analyzed and reported statistically. The use of averages is not valid in many circumstances, as many a man has drowned in waters averaging only 18 inches deep. Such an approach, necessary to the proper application and evaluation of many test results, is too rarely applied to investigations of this kind.

Very recently, we of the John Deere Research & Engineering Center have been using an electronic digital computer to investigate the dynamic performance of tractors. It has been found possible to simulate the actual field performance of a tractor, and predetermine its major design requirements ahead of its actual design, by consideration of the following factors, viz: (1) Engine power and torque characteristics, (2) torque-converter characteristics, (3) specific fuel consumption data, (4) transmission speed ratios, (5) wheel base, (6) total weight and weight distribution, (7) location of the line of implement draft, (8) traction coefficient, (9) tire slippage and efficiency, (10) variations of implement draft and rolling resistance as functions of speed.

The accuracy and consistency of the computer simulation are less subject to transient variables and the influence of extraneous factors than field tests, except under the most carefully controlled conditions. This permits performance characteristics to be closely predetermined prior to the actual design and greatly reduces development time. By evaluating the many variables contributing to implement and tractor performance and establishing their relationships and effects to a point where valid equations may be established, inestimable help can be afforded tractor design engineers. This would be reflected in the production of tractors capable of maximum performance of minimum operation cost, and adaptable to widely varying field conditions and requirements.

The Land Locomotion Research Branch of the Tank Automotive Command in Detroit has done extensive work in investigating tire- and track-soil relationships as applied to automotive off-the-road operations. Although "locomotion" and "traction" are different things, both involve common factors. Coordination of these investigations with those of this Tillage Laboratory would be of great service. In this connection, the SAE Tractor Tire Committee analyzed a portion of their field data in accordance with the procedures developed by the Tank Automotive Command, and found that the conclusions agreed within a fraction of a percent with those arrived at using the procedures determined here at Auburn. Considering that the two procedures were developed independently, and based upon widely differing backgrounds of experience, this close correlation was remarkable. Further knowledge of terrain values which affect locomotion and drawbar performance is of paramount importance in a competitive economy. Correlation of the findings of the two groups is greatly to be desired, since it would greatly extend the field of knowledge in this area, which so significantly affects tractor performance.

At present, there is increasing concern in regard to reducing, or better yet, eliminating, any damage to the soil as the result of soil compaction by tractors and implements. In addition to the work being done at our Universities and Experiment Stations, the American Society of Agricultural Engineers organized a Soil Compaction Committee to deal with the engineering aspects of these problems, and has taken the initiative in forming an intersociety committee including representatives of the American Society of Agronomy, the Soil Science Society, in addition to ASAE representatives. Work is now under way in at least three distinct categories, which must be pursued simultaneously, viz:

1. Measurement of compacting forces within the soil.

2. Measurement of the physical effects upon the soil resulting from compaction.

3. Evaluation of the effects of soil compaction, in terms of plant growth, root penetration, etc.

This Laboratory is in a unique position to afford leadership in this entire area of research.

It is to be expected that as more power is packed into a given tractor "package," both tillage and harvesting speeds will increase. If damaging soil compaction is to be avoided, advantage must be taken of the entire tractor weight to develop the necessary draft. Conceivably, if some way can be found to manufacture them economically, 4-wheel-drive tractors might come into greater use. This introduces many problems regarding which we have little or no knowledge, such as the degree of soil compaction resulting from two successive passes of relatively large driving tires, equally loaded, as compared with the successive passage of a small, lightly loaded front tire and a large, heavily loaded drive wheel tire. When the front and rear tires of a 4-wheel-drive tractor are driven at the same speed, and slippage is held constant, just what are the resulting effects upon the soil? It is in areas such as this that the findings of the Laboratory can be of inestimable value.

Our visit here has resulted in a widening of acquaintances and a better understanding of our common problems. As we learn more about the work of the Laboratory and its staff and their approach to problems involved, our own thinking is stimulated and our efforts challenged. In the interest of avoiding duplication of efforts and to effect a more speedy solution of our common problems, it is hoped that ways may be found to combine our talents and efforts. Such situations are frequently synergistic, in that the combination of efforts is frequently far more fruitful of results than the sum of the individual efforts of the participants working alone.

In conclusion, I would repeat that today can mark a real "commencement"--a new era of research and progress is ours if we want it. Let's go after it!

Dr. Carleton: Thank you, Mr. Worthington. I think we are beginning to see that our research work is cut out for us. Whenever we reach the place where we work with things we can't see, things we can't measure, and other things we don't know about, and then set up equations and feed them into an electronic computer and come out with the answer, we will be really making progress. I hope you have at least two more questions on your list by now.

Our next speaker is in farm tire development with the United States Rubber Company. Mr. Forrest has been a U. S. Rubber man from the start. He graduated from Kalamazoo College in Michigan in 1934. He has served with U. S. Rubber successively in field service engineering, in product design as product engineer, as assistant manager of tire design; and for the last few years has been manager of farm tire development.
Mr. Forrest.

TRANSPORT

P. J. Forrest[1]

We should like to take this opportunity to speak for the Rubber Industry and express our appreciation for the valuable service the National Tillage Machinery Laboratory has performed for the nation's farmers and our Industry. Our's is truly a "Nation on Wheels" and the modern farm exemplifies the efficiency of machines on rubber tired wheels. This Laboratory has had a large part in advancing the development of farm machines and tires to their present level of performance.

Shortly after World War II, our Mr. J. W. Shields, long associated with farm tires, tractors, and implements, recognized the need for research of tractor tire design fundamentals. The Tillage Machinery Laboratory had controlled facilities and a wide variety of representative soil types, ideal for testing tractor tires.

A cooperative test project was worked out with the Tillage Machinery Laboratory, and the U. S. Rubber Company designed and built a machine to facilitate the test of tractor tires. A series of special tires was provided, featuring variations in height of lug, angle of lug, and lug spacing. The test portion of this project began in 1948 and was completed in 1950.

Since that time many additional tests have been conducted by the Laboratory with truck tires, military tires, flotation tires, low section height tires, methods of oversizing rear tractor tires and the effect of rim width on tire performance to name some of the major projects. The maze of data accumulating from these laboratory tests generally boils down to a few straight-forward conclusions which guide future industry applications and lead to further new developments.

One measure of the degree of progress made for the American farmer is indicated by the amount of transport equipment in service on the farm. A short time ago, we visited a rather small farm--less than 400 acres--and counted 69 rolling tires on various pieces of equipment. It is estimated that as of January 1957, there were well over 14 million vehicles and machines employed in farm service. Each succeeding year brings improvements in machines providing higher efficiency, lower production costs, and a reduction of the overall work load of the farmer.

In the field of agricultural transport the pneumatic tire has played a key role in the development of modern tractors and machines. It has not, however, been without its limitations and performance problems. At the present time our transport problems may be divided into two broad classifications--off-the-road and on-the-road.

Pursuing the off-road classification, for the past decade there has been a significant trend to higher and higher horsepower in farm tractors. This is in keeping with the development of implements driven by the tractor PTO and the requirement for larger more versatile machines for multi-purpose work. This extra power may also be used for such activities as clearing, earthmoving, land reclamation and leveling, irrigation, ditching or trenching, front end loaders and scrapers.

While the higher horsepower is primarily intended for auxiliary purposes, when tractors are used for heavy work, the extra power is used as draw-bar pull. The resulting higher torque under heavy draw-bar loads imposes far greater demands on the tires.

The principle function of rear tractor tires is to transmit engine horsepower to draw-bar pull. Tractor engine power is transmitted through the axle and wheel down to the tire. The tread of the tire, embedded in the earth and restrained by the draw-bar load, does not move until the body of the tire is literally wound-up like a spring. When

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sufficient tension is built up, the tread begins to act. The increased torque of modern machines working against the higher draw-bar loads, tends to wind the tire up faster and tighter before it responds.

Maintenance of correct inflation pressure stiffens the tire so it may absorb higher torque loads without damage. The tire then becomes a more rigid member of the axle, wheel and tire combination providing increased resistance to buckling with a resulting reduction in tire quality problems such as radial cracking.

The Tire Industry has been stressing the importance of maintaining adequate inflation pressures through educational programs. Minimum inflation pressures have also been established for all popular sizes.

Some thought is being given to establishing capacity ratings for rear tires on the basis of their ability to absorb torque loads rather than the present basis of static loading. The Tire Industry needs help on this problem and also a better understanding of what is involved in tire buckling.

Another off-the-road problem that is beginning to assume major proportions is that of soil compaction and the resultant effect on the formation of sub-soil "pans" which retard plant growth. Tractors require heavy loads on the rear tires to achieve maximum traction when it is needed. Because it is inconvenient to alternate, the extra weight on the tires, or in them, as the case may be, is usually maintained at the maximum level. This contributes to the problem to a large degree and it would be very beneficial if the extra weight were removed when doing lighter work.

Some farmers, notably in North Dakota and Minnesota, are finding that dual rear tires provide the necessary degree of flotation for drilling or planting after preparation of the soil. They claim the extra tire and rim equipment pays for itself in 2 to 3 years. Perhaps 4-wheel-drive tractors with their more favorable power-weight distribution may be a future answer to this problem.

On-the-road, we have one major tire problem - fast treadwear. In the past several years there has been an increasing trend to transport agricultural equipment over the road especially for custom harvesting and multiple farm operation. When tires designed to provide high traction in field service are exposed to hard road surfaces they scrub out and wear irregularly and rapidly. Higher inflation pressures help to minimize this condition but it's hard to get the farmer to change tire pressures from one day to the next. Perhaps tires should be considered expendable under severe operating conditions of this nature. A possible solution may be the provision for a better balance between traction and wear rate in the design of future tires.

For future consideration, the military services, in conjunction with the rubber industry, have developed new rubber products to achieve mobility under most all conditions. These developments include:

1. Band tracks with low ground pressures.

2. Rolligons - extremely low pressure and flexible air containers on which the vehicle rolls.

3. Sand tires - for strictly flotation work.

Rubber band tracks probably offer the greatest promise for application to agricultural transport equipment. They provide low ground pressure intensities - 30 to 40 percent of wheel tractors, are light weight, and may be operated at much higher speeds than metal track vehicles. Further development is required to adapt band tracks to agricultural machines.

Rolligons operate at extremely low ground pressure intensities but have the disadvantage of being large and cumbersome.

Sand tires featuring high flotation properties have already been adapted to agricultural equipment--principally in Florida on trucks and tractors and on some types of harvest equipment and sprayers used generally.

In discussing the subject of "Transport" it is obvious that we have presented views principally from the standpoint of tire applications. That is because we believe the tire is one of the most important links in the chain of transmission from motor power to vehicle movement.

One of the outstanding examples of research accomplishment for agriculture is the work on the soil erosion problem in the dust bowl area. By cooperative effort, research pointed the way to better methods of soil conservation and industry provided the tools to do the job. Today, this cooperative teamwork approach of research - development has become an established pattern for the solution of many major problems.

If we are to keep pace with our national economy and increasing population, a continued and expanded research program to serve the needs of agriculture and supplier industries is vital.

Thank you.

Dr. Carleton: Mr. Forrest has given us a good discussion of some of the ways by which we are trying to solve problems of transporting difficult vehicles.

Our last speaker on the panel, Mr. C. R. Foster, is Chief of the Flexible Pavement Branch, Soils Division, of the Waterways Experiment Station. Not long ago I was privileged to review a series of articles, authored by members of the Waterways Station, dealing with compaction and the forces transmitted in the soil. We have here people who are directly concerned with military problems and yet, as Mr. Worthington suggested, it behooves us all to take advantage of the information existing in related fields and to try to tie the information all together into one package for the best solution of a particular problem.

Mr. Foster has been with the Corps of Engineers since 1936. He has worked on various problems including those associated with dams and levees. He is presently working on the problem of flexible pavements and is to discuss with us the relation of that work to trafficability. Mr. Foster.

SOIL TRAFFICABILITY

C. R. Foster,[1] S. J. Knight,[2] A. A. Rula[3]

Introduction

A program of research has been under way by the Corps of Engineers for a number of years to develop instruments for predicting the capacity of a soil to support Army vehicles in military operations. The results of some of the studies may be useful in solving problems concerned with plowing soil and transporting supplies and commodities under off-road conditions.

Since World War II the ability of natural soils to support military vehicles has been the subject of study by the Army Mobility Research Center, Soils Division, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Incomplete knowledge of off-road performance during World War II sometimes resulted in grave consequences. For example, the landing at Iwo Jima may have been less costly if the vehicles had been able to negotiate the soft, loose, powdery, volcanic ash on the beaches without difficulty. There were other instances in which incomplete understanding of relationships between soil conditions and vehicles resulted in tactical setbacks. In a plan to invade Japan by overland means, these experiences and the trouble anticipated in traversing the rice paddies led to a study of soil conditions that could and could not support the various military vehicles planned for use in the invasion.

The Waterways Experiment Station assisted in this study of trafficability in the summer of 1945 and has been engaged in this work and its more important corollary, the study of means to improve the mobility of military vehicles in soft soils, ever since. Nuclear warfare as foreseen for the future demands rapid assembly of battle forces, a quick strike, and immediate and wide dispersal before retaliation. Roads and highways can no longer be depended upon. In the future our vehicles must travel cross country if we are to be victorious. Therefore, the need for increased knowledge of trafficability and increased mobility of vehicles is greater today than ever before.

Trafficability of Soils

To be adequate for a vehicle, a soil must have sufficient bearing capacity to prevent the vehicle from sinking too deeply and sufficient tractive capacity to provide the necessary forward thrust of the vehicle's wheels or tracks. Bearing capacity and tractive capacity are both functions of the sheer strength of a soil. Usually an immobilization of a vehicle is caused by a concurrent failure in bearing and traction and it is not possible to separate the two effects. Tractive failure can occur on a soil with adequate bearing strength, as when a rubber-tired vehicle merely spins its wheels but does not sink appreciably, but sinkage failure does not occur without being accompanied by tractive failure.

Instruments

Bearing-tractive capacity is measured in terms of cone index, which is the pounds of force that must be applied to the handle of the instrument shown on fig. 1 per square inch of end area of its cone tip in order to force it into the ground. The right circular, 30-deg cone, not visible in the photograph, has an end area of 1/2 sq in. The cone is pushed slowly downward and readings of the dial gage are made at desired vertical increments.

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[3] Engineer, Army Mobility Research Center, Flexible Pavement Branch, Soils Division, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Figure 1. Measuring cone index with cone penetrometer

Many soils whose strengths are low in situ will become even weaker under the action, or remolding effect, of a vehicle. In order to estimate the cone index that will prevail under the moving vehicle, a remolding test was devised. This test consists of measuring the cone index of a sample of soil confined in small cylinder before and after pounding it with 100 blows of a 2-1/2-lb hammer falling 12 in. A "remolding index" is obtained by dividing the cone index of the soil after it has been pounded by its cone index before the blows were applied. Fig. 2 illustrates the various stages of this test. A "rating cone index," the final measure of a soil's trafficability, is obtained by multiplying in-situ cone index by remolding index.

Vehicle performance - cone index correlations

From data collected in hundreds of tests with several types of military vehicles on fine-grained soils (silts, clays, loams, etc.) it has become feasible to predict the performance of these vehicles on the basis of rating cone index. If the rating cone index of a given area is known, one can confidently predict whether a given vehicle will be able to cross the area once, whether 50 vehicles can cross in the same path, how heavy a load the vehicle can tow through the area, or how steep a slope the vehicle can climb.

The following tabulation shows the rating cone index necessary for completion of one pass and 50 passes of a few typical military vehicles. Cone indexes required for 50 passes of a vehicle up a given slope or for 50 passes towing a given load on level terrain may be determined by using the curves shown on fig. 3. Towing forces required for vehicles may be estimated using the curves on fig. 4.

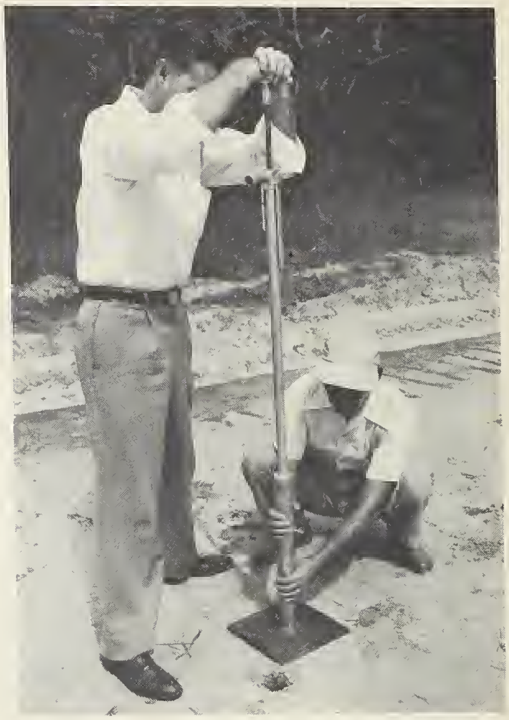
Vehicle	Description	Rating Cone Index for 1 Pass	Rating Cone Index for 50 Passes
M29C weasel	5,500-lb, tracked, amphibious cargo carrier	20	25
D7 engineer tractor	35,000-lb Caterpillar-type constr. tractor	30	40
M48 tank	90,000-lb medium tank	40	50
3/4-ton weapons carrier	7,400-lb (with load of 1,500 lb) 4x4 truck	50	65
2-1/2-ton cargo truck	16,300-lb (with load of 5,000 lb) 6x6 truck	45	60

Using the data collected in actual vehicle tests, a system was developed for evaluating the effects of a vehicle's characteristics (weight, contact pressure, etc.) in terms of the cone index required for the vehicle. The system comprises four formulas--one formula for self-propelled tracked vehicles, another for self-propelled wheeled vehicles, and one each for towed tracked and wheeled vehicles. These formulas are shown in appendix A. The formula for self-propelled tracked vehicles has been verified by several tests on vehicles not used in its development and was found to be entirely satisfactory. The formula for self-propelled wheeled vehicles has only been checked by a few tests, and while these tests bear out the formula, additional tests are needed before it can be fully accepted. No opportunity has as yet presented itself for checking the two formulas for towed vehicles.

Soil classification

The principal influence on the rating cone index of a fine-grained soil is the amount of water it contains. Almost any soil in a comparatively dry state is trafficable to all military vehicles, but if its moisture content is increased, its trafficability may be

Taking sample



Loading cylinder

Measuring cone index before
blows are applied

Applying blows

Figure 2. Remolding test equipment and procedures

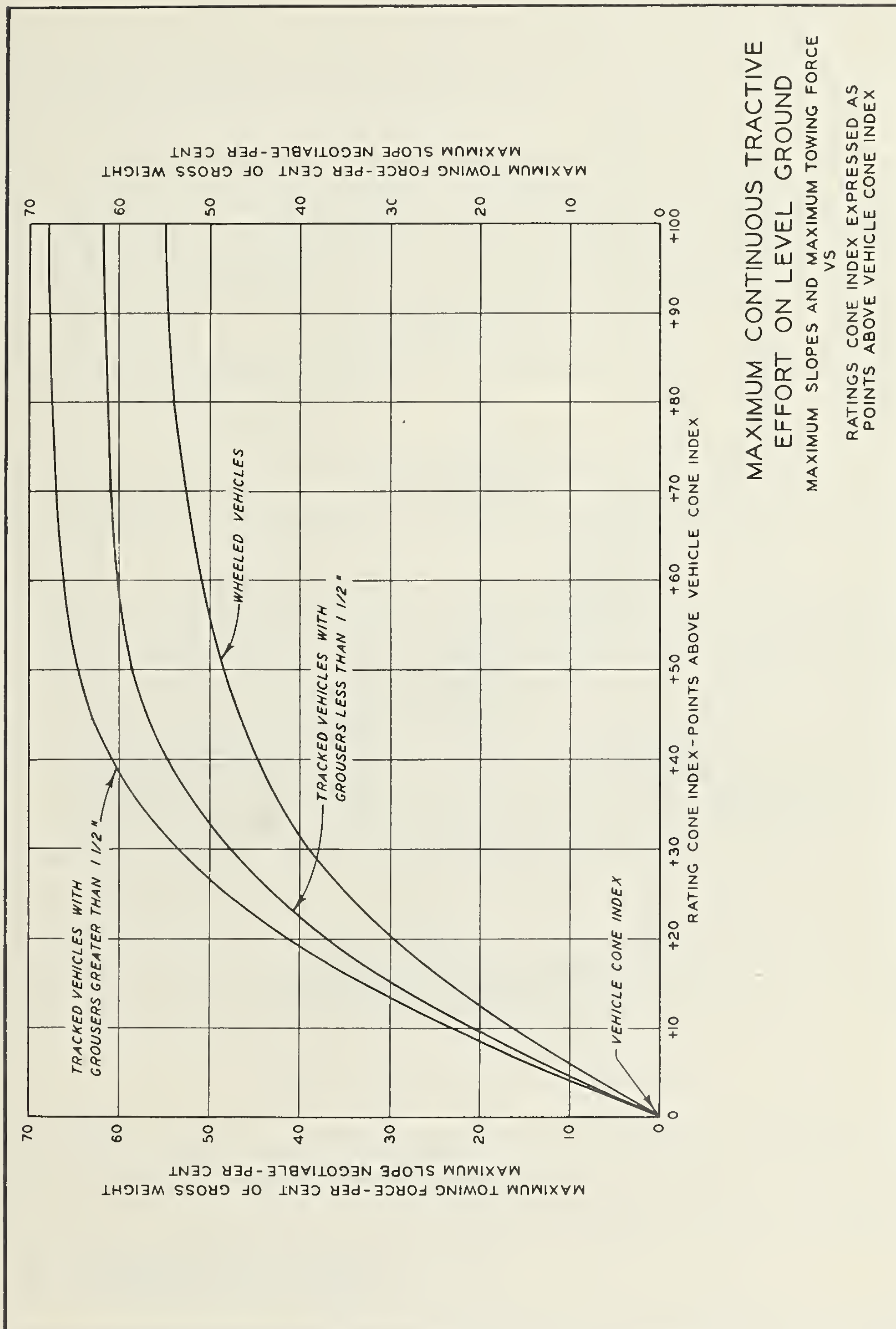
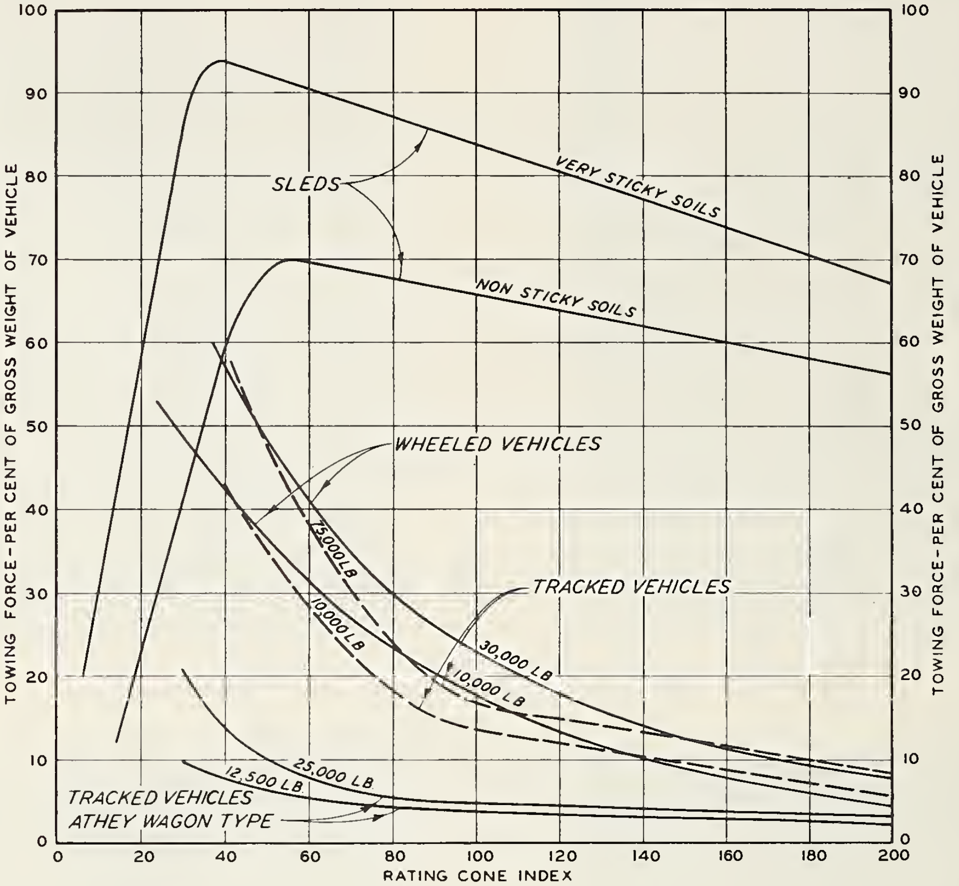

MAXIMUM CONTINUOUS TRACTIVE
EFFORT ON LEVEL GROUND
MAXIMUM SLOPES AND MAXIMUM TOWING FORCE
VS
RATINGS CONE INDEX EXPRESSED AS
POINTS ABOVE VEHICLE CONE INDEX
MAXIMUM TOWING FORCE-PER CENT OF GROSS WEIGHT
MAXIMUM SLOPE NEGOTIABLE-PER CENT
RATING CONE INDEX-POINTS ABOVE VEHICLE CONE INDEX
WHEELED VEHICLES
TRACKED VEHICLES WITH
GROUSERS LESS THAN 1 1/2"
TRACKED VEHICLES WITH
GROUSERS GREATER THAN 1 1/2"
VEHICLE CONE INDEX
0
+10
+20
+30
+40
+50
+60
+70
+80
+90
+100
0
10
20
30
40
50
60
70

Figure 3



NOTE: THE TOWING FORCE REQUIRED IN AN AREA WHOSE CONE INDEX IS 20 POINTS OR MORE BELOW THE MINIMUM FOR THE VEHICLE MAY EQUAL OR EXCEED THE WEIGHT OF THE VEHICLE.

TOWING FORCE REQUIRED ON LEVEL GROUND

Figure 4.

reduced to the point where only certain vehicles can traverse it. A further increase in moisture may render the soil untrafficable to all vehicles. It is apparent that moisture conditions must be recognized in any evaluation of the trafficability of a soil, and further that soils must be at similar or equivalent conditions of moisture in order that they may be rated fairly in comparison with each other.

Waterways Experiment Station studies have shown that in a humid climate the top 12 in. or so of a given fine-grained soil attains a certain maximum moisture early in the wet season and maintains this moisture with very little deviation throughout this season. This field maximum offers a practical moisture datum for evaluation of the trafficability of soils, at least in humid locations in the United States. Although actual moisture content varies widely from soil type to soil type, a soil whose moisture content is at field maximum is at its poorest condition from a trafficability standpoint.

A scheme of classifying soils from the standpoint of their trafficability in the wet season is shown in the following table.

Remote estimation of trafficability

In military situations it is not always possible to enter an area and make cone penetrometer measurements. Therefore, a substantial amount of study has been devoted to estimating trafficability when physical contact with the soil is denied.

Soil types can be identified from aerial photos and, once they are identified, their strengths can be estimated on the basis of their moisture contents. Use of the following table will provide a rough estimate of soil strengths in the wet season, but greater accuracy is desired by the Military. Accordingly, studies are in progress to permit the prediction of the amount of water a given soil will contain at any time and, from the water content, the strength it will have. With the cooperation of the U. S. Forest Service, methods have been developed that permit the prediction of moisture content from rainfall with very good accuracy. Mainly, these methods consider two phenomena, accretion and depletion. The amount of moisture that a soil will accrete from rainfall depends mainly upon the moisture content of the soil before the rain and the amount of rain. Graphs and charts have been constructed that permit fairly accurate prediction of accretion quantities for all soil types. Soil moisture is depleted by evaporation, transpiration, and drainage. Depletion rates vary mainly according to season and soil type. Hundreds of soils in widely scattered locations of the United States have been used in developing accretion and depletion data, and these data are now being analyzed to develop criteria that will permit extrapolation to other soils and climates of the world. Details are contained in a reprint from Soil Science Society of America Proceedings, vol. 20, No. 3, July 1956, Predicting Moisture in the Surface Foot of Soil, by Carlson, Reinhart, and Horton.

Mobility Improvement in Soft Soils

Unfortunately, progress in improving mobility of vehicles in soft soils has not matched progress in the trafficability studies. Tracked vehicles of today, despite their more powerful engines, more facile steering, sturdier parts, etc., are not noticeably better off-road performers than they were many years ago. It is true that off-road performance of wheeled vehicles has improved materially through the use of larger, more flexible tires, but no really outstanding changes in fundamental traction principles have been demonstrated in the last several years.

Waterborne vessels have improved through the years because of the science of hydrodynamics; the aircraft is what it is today because of aerodynamics. Unfortunately there is no "soildynamics" to provide the proper science background for the improvement of traction in land vehicles on soft soils. This is a science yet to be created and developed. Without a fuller understanding of what takes place when a wheel or a track as we know it today moves through a soft soil, there is little hope that improvement in mobility will reach major proportions. The newly created Army Mobility Research Center

TRAFFICABILITY CHARACTERISTICS OF SOILS IN WET SEASON

Group	Soils	Unified Soil Classification System	Probable Cone Index Range	Probable Remolding Index Range	Probable Rating Cone Index Range	Slipperiness Effects	Stickiness Effects	Comments
A	Coarse-grained, cohesionless sands and gravels	GW, GP, SW, SP	80 to 300	>1	80 to 300	Slight to none	None	Will support continuous traffic of military vehicles with tracks or with high-flotation tires. Moist sands are good, dry sands only fair. Wheeled vehicles with standard tires may be immobilized in dry sands.
B	Inorganic clays of high plasticity, fat clays	CH	55 to 165	0.75 to 1.35	65 to 140	Severe to slight	Severe to slight	Usually will support more than 50 passes of military vehicles. Going will be difficult at times.
C	Clayey gravels, gravel-sand-clay mixtures Clayey sands, sand-clay mixtures Gravelly clays, sandy clays, inorganic clays of low to medium plasticity, lean clays, silty clays	GC SC CL	85 to 175	0.45 to 0.75	45 to 125	Severe to slight	Moderate to slight	Often will not support 40 to 50 passes of military vehicles, but usually will support limited traffic. Going will be difficult in most cases.
D	Silty gravels, gravel-sand-silt mixtures Silty sands, sand-silt mixtures Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts Organic silts and organic silty clays of low plasticity Organic clays of medium to high plasticity, organic silts	GM SM ML and CL-ML MH OL OH	85 to 180	0.25 to 0.85	25 to 120	Moderate to slight	Slight	Usually will not support 40 to 50 passes of military vehicles. Often will not permit even a single pass. Going will be difficult in most cases.

of the Corps of Engineers proposes to conduct studies to determine the magnitudes and distribution patterns of stresses induced by moving vehicles and the means of measuring the ability of soils to resist these stresses. Preliminary work has already begun and a new laboratory is being constructed in which vehicle-soil relationships can be studied under controlled conditions. It is hoped that rational bases for the improvement of military vehicles of the future will be forthcoming from these studies.

Application to Problems of Tillage and Tractive Equipment

This paper has offered no magic solution to the tillage or tractive problems encountered by the farm operator. However, it is believed that some of the findings from the Waterways Experiment Station trafficability studies may give the persons doing research in these problems a better understanding of the effects of soil strengths and help toward solutions of the tillage problems and incidently may help toward the solution of the mobility problem.

Specifically, it is suggested that:

a. The cone penetrometer and remolding test be used to measure quantitatively the soil strength, or the trafficability, of the various soils that are tested.

b. The formulas in appendix A be studied to determine if they evaluate properly the ability of tractors.

c. The principles for predicting soil moisture be considered for use in determining whether or not soil conditions are proper for tillage and for the support of the traffic of trucks and trailers.

Appendix A: Mobility Index

The mobility index is a dimensionless number obtained by applying certain characteristics of a vehicle to the formulas given subsequently. The mobility index can then be applied to the curve shown in fig. A1 to determine the vehicle cone index.

Self-propelled tracked vehicles

$$\text{Mobility index} = \left(\frac{\text{contact pressure} \times \text{weight factor}}{\text{track factor} \times \text{grouser factor}} + \text{bogie factor} - \text{clearance factor} \right) \times \text{engine factor} \times \text{transmission factor}$$

wherein,

$$\text{contact pressure} = \frac{\text{gross weight in lb}}{\text{area of tracks in contact with ground in sq in.}}$$

weight factor: less than 50,000 lb = 1.0
50,000 to 69,999 lb = 1.2
70,000 to 99,999 lb = 1.4
100,000 lb or greater = 1.8

$$\text{track factor} = \frac{\text{track width in in.}}{100}$$

grouser factor: grousers less than 1.5 in. high = 1.0
grousers more than 1.5 in. high = 1.1

$$\text{bogie factor} = \frac{\text{gross weight in lb divided by 10}}{(\text{total number of bogies on tracks in contact with ground}) \times (\text{area of 1 track shoe in sq in.})}$$

$$\text{clearance factor} = \frac{\text{clearance in in.}}{10}$$

engine factor: 10 or greater hp per ton of vehicle wt = 1.0
less than 10 hp per ton of vehicle wt = 1.05

transmission factor: hydraulic = 1.0; mechanical = 1.05

Self-propelled wheeled vehicles

$$\text{Mobility index} = 0.6 \left[\left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{tire factor} \times \text{grouser factor}} + \text{wheel load} - \text{clearance factor} \right) \times \text{engine factor} \times \text{transmission factor} \right] + 20$$

wherein,

$$\text{contact pressure factor} = \frac{\text{gross weight in lb}}{\text{tire width} \times \text{rim diam} \times \text{No. of tires}}$$

weight factor: greater than 35,000 lb = 1.1
15,000 to 35,000 lb = 1.0
less than 15,000 lb = 0.9

tire factor = 1.25 x tire width in in. divided by 1.00

grouser factor: with chains = 1.05
without chains = 1.00

wheel load = $\frac{\text{gross weight in kips}}{\text{No. of wheels}}$ (wheels may be single or dual)

clearance factor = $\frac{\text{clearance in in.}}{10}$

engine factor: greater than 10 hp per ton = 1.0
less than 10 hp per ton = 1.05

transmission factor: hydraulic = 1.0; mechanical = 1.05

<u>Towed tracked vehicles</u>

$$\text{Mobility index} = \left(\frac{\text{contact pressure} \times \text{weight factor}}{\text{track factor}} + \text{bogie factor} - \text{clearance} \right) + 30$$

wherein,

contact pressure = $\frac{\text{gross weight in lb}}{\text{area of tracks in contact with ground in sq in.}}$

weight factor: 15,000 lb or greater = 1.0
below 15,000 lb = 0.8

track factor = $\frac{\text{track width in in.}}{100}$

bogie factor = $\frac{\text{gross weight in lb divided by 10}}{\text{(total No. of bogies on track in contact with ground) x (area of 1 track shoe in sq in.)}}$

clearance = clearance in in.

<u>Towed wheeled vehicles</u>

$$\text{Mobility index} = 0.64 \left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{tire factor}} + \text{axle load} - \text{clearance} \right) + 10$$

wherein,

contact pressure factor = $\frac{\text{normal tire pressure in lb per sq in.}}{2}$

weight factor: 15,000 lb per axle or greater = 1.0
12,500 to 14,999 lb = 0.9
10,000 to 12,499 lb = 0.8
7,500 to 9,999 = 0.7
less than 7,500 lb = 0.6

tire factor: single tire = $\frac{\text{width in in.}}{100}$

dual tire = $\frac{\text{1.5 x width in in.}}{100}$

axle load = $\frac{\text{axle load in lb}}{1000}$

clearance = clearance in in.

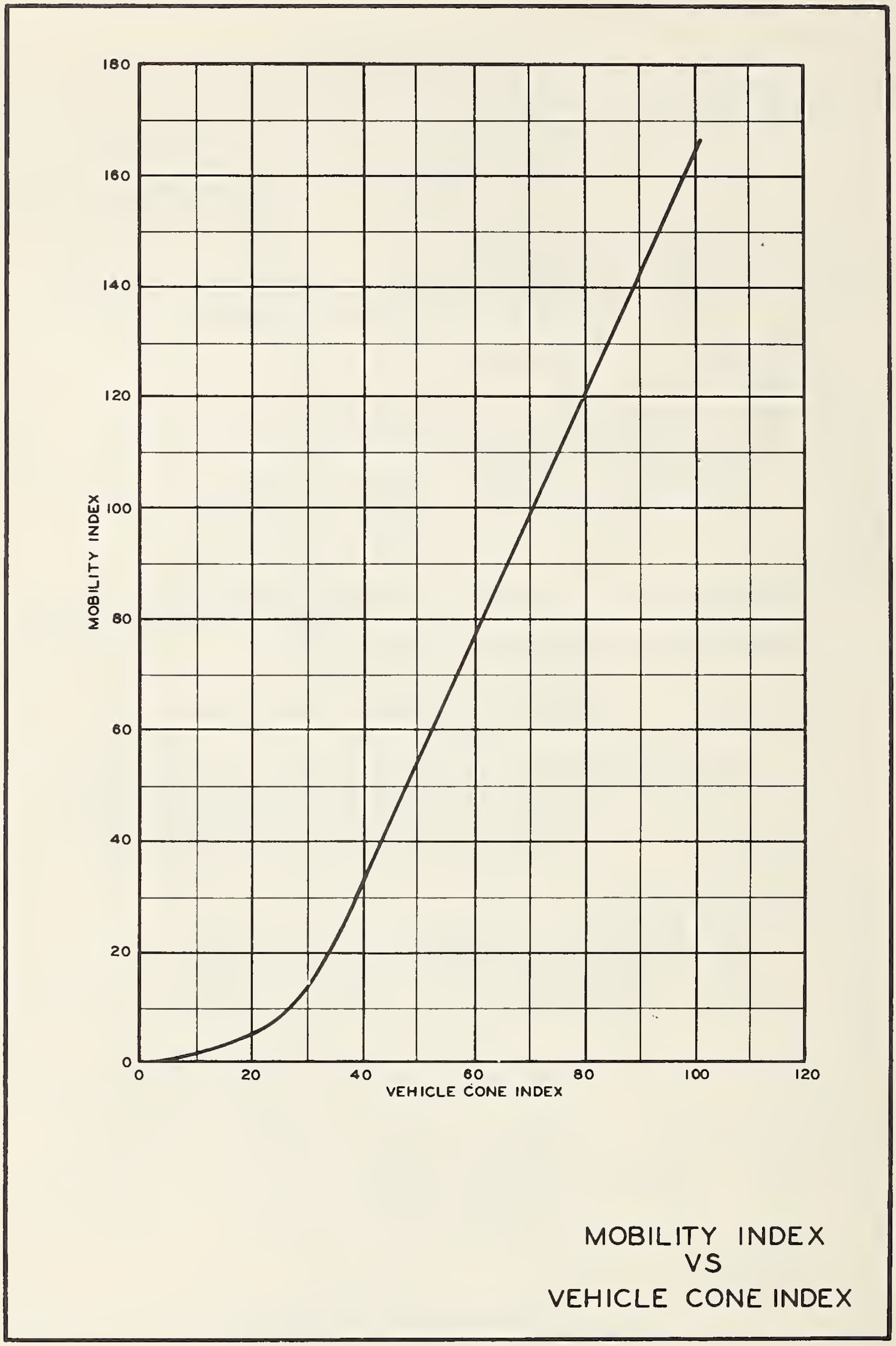

180
160
140
120
100
80
60
40
20
0
MOBILITY INDEX
0
20
40
60
80
100
120
VEHICLE CONE INDEX
MOBILITY INDEX
VS
VEHICLE CONE INDEX

Figure A1

Dr. Carleton: To resume quickly, we have discussed this morning tillage and crop relationships, and equipment, and soil relations. Individual papers have been handled by specialists in tillage equipment, tractor stability, trafficability, and soil properties. We will now have the questions.

Dr. Cooper: I wanted someone else to ask the first question but I have two or three. I would like to ask Mr. Worthington if he would elaborate a little more on the types of problems that he thinks that we can use the computers on. We are very much interested in this tool to help with analyses. In some physical relations we know we can do them without the statistical approach and without elaborate computers to work on, but in some types we know that the computers are going to be very helpful. I just wondered if he could elaborate a little bit on a specific example of that.

Mr. Worthington: To answer that question, we have not done enough work with the computer yet to discuss more than just one problem. In that, we took the characteristics of tires on stubble land. We know the efficiency with respect to traction coefficient and slippage. Those are variables inter-related, or functions of each other. That usually is shown as curves. To feed this information into a computer, you take those curves and punch the cards from them. We have certain characteristics of rolling resistance of front wheels, which is a function of the tire size and soil condition, and it increases with speed, and it is, of course, a function of the weight imposed on it. The weight that is imposed on the front wheels of a tractor is again a function of drawbar pull, among other things, and rear axle torque. Those variables come in. So you set up an equation for the rolling resistance of the front tires in terms of the drawbar pull applied to that particular type of soil. That brings in the findings that you have discovered - the amount that the tire sinks in and things of that kind. You draw those curves and again you punch that information on your cards and feed that into the memory of your computer. Then you have your engine torque curves, it is a characteristic of the engine, and you feed that into your computer, because you are pulling this tractor, perhaps, under load. You are exploring the bounds of performance.

Then what you are interested in knowing is what are the characteristics of this tractor with variations of load. We are required to design a tractor to do a certain job. The soil resistance to pulling an assumed tool again determines one of the variables there, and the resistance of a plow is again a function of speed that follows a curve, for which you can set up an equation. From experimental work we have done to date, we have those characteristic data over the present and future speeds for existing tools. We don't have for future tools, as the tools haven't been designed yet. So, again we have the performance data which we put onto a deck of cards which we feed in. Now, if you are using the speed in miles per hour, and you plot the drawbar horsepower for a conventional transmission, you get a series of curves that tend to drop off. Each of these curves represents a different gear ratio. So we select a curve which represents a third speed ratio. Into the computer you feed the deck of cards for a torque converter and this speed ratio. All you have done with this data is to put in between the engine and the transmission the characteristics of a torque converter and the answers come out. In other words, with a digital computer - I am speaking of digital and not analog computers - a digital computer solves by a series of approximations.

[Mr. Worthington illustrated how a digital computer could be used to aid in the problem of designing an involute form of a gear tooth to a desired accuracy. He concluded his discussion as follows:]

> The computer was put in for inventory control and to handle the payroll, and when we asked our management to do a little work with it (about this time last year), they said, "Well, put him on it until Christmas time, and if it doesn't show any results by that time, take him off." He went on until Christmas time, he is still on it, and I think that we are going to have two men on it now, and probably a whole crew on it from now on out. Those are just examples of things. It takes a lot of stretch of the imagination. I've never been able to stretch my imagination that far. I only thought that we would take one problem and get our foot in the door, and as

soon as we got one problem, then we would have other uses injected and that's about the thing we are talking about. In your work here, there are computers around the country and we will be very glad to work with you and let the man who is doing our work (he is not a computer man, he is an electrical engineer) help you. He's got to cut his eye teeth on soils some of these days and he might as well do it sooner as later. Does that answer your question?

Dr. Cooper: That does, very well. We would like to get him on some soil problems. Dr. Carleton, I'd like to just make a comment about what Mr. Foster said. You know, we consider agricultural engineers any engineer who contributes to agriculture, so we are happy to have the civil engineers included as agricultural engineers, as well as the mechanical and electrical, and the others.

Dr. Buchele: I would like to ask a question of Mr. Forrest. You mentioned the relation between tire pressure and the performance of that tire. Would we improve the life of the tire and the performance of the tire if we had on our tractor a device that would inflate the tire according to the pull that was being developed by the tractor?

Mr. Forrest: As long as that inflation would be within the capacity limit of the tire to sustain that inflation, yes, it would be very beneficial, I should think. That is, to the tire. Now, in so far as traction is concerned, we actually get a higher drawbar value on tires that are operated at a reduced inflation pressure, but that is always to the degradation of the tire. Do you follow me? In other words, when we fail to maintain a sufficient inflation pressure, two things happen. First, the deflection of the tire increases and the effect of torque "winding up" that tire becomes more severe. So to answer your specific question, yes, it would be greatly beneficial if we were to have a compensating method of raising or lowering the inflation pressure in tractor tires, as long as it remained within the limits which provide reasonably good tire durability.

Dr. Carleton: I'd like to ask if you would comment on this matter of band tracks. I think that was brought up in the discussion as one possible thing on which there would be many more comments. Or is the discussion enough?

Mr. Forrest: I think that it's enough. Actually, in cooperation with the Ordnance Department, band tracks have been devised, improved, and now have actual applications. Modifications have been made which have further increased floatation ability of the track, and we have had some extremely low ground pressure intensities as a result of further developments of band tracks.

Mr. Reed: While he is on that, are you referring to the band track to replace crawler track, or what we might call now a half-track arrangement?

Mr. Forrest: I am suggesting that the possibilities of the band track be investigated for situations where we are running out of opportunities to let the wheel tractor return a reasonable degree of efficiency in its operation. In other words, where you have a high floatation problem, or where you have a high soil compaction problem, if it is true that low ground pressure intensity contributes to a reduced effect of compaction, then here is a possible tool. The application is undoubtedly considerably more expensive than wheel tractor tires and therefore that might out-rule its possibility. But I believe that for certain specialized types of farming, where we have light soils and low ground pressure intensities are required, here is a possibility. The percentage of drawbar pull in relation to the tractor weight is considerably higher with these rubber band track applications than it is with wheel tractors.

Mr. J. I. Davis, Sr.: What does Ford call this half-track of theirs that they put on?

Reply from floor: Bombardier, isn't it?

Question from floor: How much do you sacrifice in maneuverability when that is wrapped around the wheels?

Mr. Davis: There is a third wheel on there that it wraps around. It is maneuverable all right.

Mr. Forrest: My experience is very limited, so I beg to be excused from answering that question.

Dr. Carleton: We have some Ford people here. Maybe they want to answer it.

Mr. Richey: Actually, I know they are popular in some logging work, but we haven't handled them ourselves, as we handle tires and tubes. They are quite expensive, as I understand.

Mr. Tanquary: One more about the band tracks. Has this problem of dirt getting between the track and the drive sprocket or idler been licked pretty well?

Mr. Forrest: The tracks have been modified to the extent that the situation has been quite radically improved.

Dr. Carleton: Gentlemen, I want to extend my personal thanks to you and the panel for your comments this morning. To me it has been most interesting and most constructive. I suspect if you have another question or two that you still want solved, that after the luncheon and we get into general session there will be further opportunity for questions.

It seems that life is becoming complicated. When Mr. Worthington hints at the partial replacement of engineers by computers and suggests that all the engineers have to be advanced mathematicians, I wonder if there aren't going to be a lot of engineers who will want to go into administration.

Meeting turned back to Chairman.
Session adjourned for lunch.

Noon Luncheon and Closing Meeting Combined - Friday, October 25, 1957

Dr. M. L. Nichols presiding.

Dr. Nichols: Since time is limited, and most of you are Rotarians or Kiwanians or members of some luncheon club and are used to eating and listening, I thought we would go ahead with the program, even if you have not finished eating. To me, this is the most interesting part of the program, because we certainly have to summarize and obtain direction. It's probably "carrying coals to Newcastle" to introduce Dr. McKibben to this crowd. You all know Dr. McKibben. There is nothing I can say about Dr. McKibben that you don't already know. Dr. McKibben.

PLANS FOR THE NATIONAL TILLAGE MACHINERY LABORATORY

E. G. McKibben[1]

Dr. Nichols and fellow engineers, I have a little story that would probably best illustrate my situation in relationship to the Tillage Machinery Laboratory. During the war there was a meeting of factory managers called by the military for the purpose of inspiring them to increase the production and the output from the various factories. One of these managers came back to his home factory, called in his foremen and his chief engineers and his general supervisory group and relayed the story to them. As he talked, he frequently made reference to the extreme necessity of removing bottlenecks here and bottlenecks there, etc. When he finally finished his inspirational presentation, way back in the corner, a meek little individual held up his hand and asked for attention and, when recognized, said that as he had gone through life he had observed that all bottles he had ever seen had the neck at the top. So, I'm the bottleneck so far as this particular program is concerned. Most of you here have met Dr. Carleton, who is my assistant. When we brought him in about a year ago, I emphasized to the group in Beltsville that this was an attempt to make the bottleneck twice as wide and not twice as deep. I assure you that I feel that this has been the case and I believe that others will agree. He has done very well in helping out.

I do wish to take this opportunity to express appreciation to all who have made this Seminar possible and who have taken part in it. This includes all of the staff of the Laboratory here from Director Nichols to the laboratory shop and plot workers, and it also includes many representatives of the Alabama Polytechnic Institute, particularly the Agricultural Engineering Department, the Agricultural Engineering Section of the Experiment Station, several other groups in the ARS of the Department, and Personnel and Information Divisions of the Department of Agriculture. Last, and most important of all, are the representatives we have here from the farm equipment industry, and from the action programs such as the Soil Conservation Service, who are primarily concerned with the business of farming. I do want to emphasize that many of the findings of the Agricultural Engineering Research Division of the Department, as well as Agricultural Engineering Departments of the various state public research agencies, will be of service to American agriculture and through American agriculture to the citizens who are paying the taxes only as they are incorporated into the design and into the production of the farm equipment and related industry. Certain of our findings can be taken directly to the farmer by extension workers, but many of them cannot.

The ultimate purpose of the National Tillage Machinery Research Laboratory is, I think, relatively easily stated and readily understood. It is better tillage, traction, and transport equipment for the American farmers and the most effective and efficient use of this equipment. I said the purpose is relatively easily stated and understood. I think if you'll look over the bylaws and constitution of almost any organization that you have had a connection with, irrespective of how bad the reputation of the organization might be, you would find that the objects and purposes of these organizations are relatively easy to understand and readily stated, but the problem is to get them executed in that direction, and that's the problem here. The development and execution of the best plans to accomplish this purpose are not so simple and they involve many complex relationships with many scientific, technical, and industrial groups.

As a matter of orientation, how large, how extensive is this objective? I am talking about this better equipment of various types for American agriculture. How big is that problem? This problem is of concern to every one of America's more than 4.5 million farms, as well as many thousands of estates and suburban gardens, and we probably don't visualize the extent of the application of some of the principles that we, in cooperation with other disciplines in science, may establish here in our basic research. These principles will apply to an estate, a golf course, or a suburban garden as well as

[1] Director, Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

they do to a 2,000 acre ranch. That's more than 400,000,000 acres of tillable land. It is difficult to estimate the amount of equipment involved. However, it is reasonable to assume that some of the basic problems being investigated here at the National Tillage Machinery Laboratory apply to the operation of nearly all of the more than 4.5 million tractors and 2.5 million trucks now on American farms, because a large number of these trucks do have off the road transport applications. It is difficult to know how many pieces of equipment go along with these automotive items. If we make the assumption that there are at least five pieces of tillage and transport equipment for each one of these tractors, we come up with something over 20 million pieces of equipment whose operating characteristics are related to some of the problems that are being studied under this program.

The problems of tillage, soil traction, field transport, or trafficability are not only universal so far as agriculture is concerned, but they are also complex and scientifically challenging. They involve many fields of technology and will require both fundamental and applied research on a cooperative basis with soil and crop scientists and manufacturing technologists in order to arrive at the best solutions. This is a summary or perhaps a redundant statement. As a result of the day and a half that you have been here, those of you who had any illusions about the problem being simple and easily handled have lost them by this time. I have in mind a problem that Dr. Allaway mentioned, that there still is no objective definition of degree or quality of soil tilth. There are a great many more.

We feel that the present program should be continued--let us say that the Administration, this bottleneck at least, feels that way about it--to the extent necessary to perform the basic and applied research required, and again I want to emphasize that we are very much concerned with the basic phases of this program. Although my feeling about classifying research doesn't quite check with some other people's, I'm not, in a way, too much concerned with whether the immediate problem is something that a certain group of scholars would call basic and fundamental or some other group would call applied. Our concern is whether it is done right and done well, whether as much information is obtained as possible - as much general information, as much usable information - over as big an area as possible. Are we getting the maximum out for the effort put in? This end result will require expansion of this research program to obtain the needed information for the most economical and efficient development and improvement of tillage, traffic, and traction equipment.

Such an expansion of work of the Tillage Laboratory will, of necessity, involve additional facilities and staff; and an effort should be made to secure additional facilities, which should include increased office space, a reasonable conference room - not necessarily a conference room big enough to take care of the maximum group that was here for this Seminar. But when representatives of three of the larger implement and tractor manufacturers and representatives of two or three State experiment stations and three or four of our group met after the meeting yesterday afternoon to discuss a group of papers that they are going to present at the next ASAE meeting on the basic relationships of the effect on performance and the effect on the soil of 4- and 2-wheel-drive tractors, they had to crowd around a table in Dr. Nichols' office; it was far from being the kind of a meeting place we should have for such a conference. Other needs are more equipment storage and some controlled environment laboratories. These controlled laboratories should include facilities for determining the effect of tillage practices on soil environmental conditions affecting plant growth and additional soil physical laboratories to speed up the evaluation of the reactions of the many kinds of soil through their normal range of conditions under tillage. Undoubtedly, that is a type of activity which would include some plant scientists in the same way that we have Dr. Gill here as a Soil Scientist cooperating with the relationship of machines to soil physical conditions.

This physical plant development should also include necessary additions to and improvements in the controlled tillage plot bins and the equipment for these bins. At least one silt loam, and probably several other soil types, should be added as well as soil bins designed specifically for the investigation of subsoiling equipment. Our situation here for

studies under controlled conditions for deeper tillage equipment is not very satisfactory. We have only about 2 feet before we get down into the special subsoil that has been put in for drainage purposes; it would pretty well damage the bin set-up for shallower tillage tests if we should go too deep.

To be fully effective, the Laboratory staff and facilities should be expanded so that a first-hand study of the problems in the field can be made, to evaluate the severity and extent of tillage problems. This would include transportation and other special equipment for field studies supplementing the usual field implements and facilities of cooperating agencies. It isn't our idea that we would have a big enough program here to take over nationally all of the research on tillage and related problems. What we would want is adequate facilities and staff to cooperate most effectively with the agencies that are now scattered over the Nation.

The expansion of the program of the Laboratory to serve nationally, and with the present American system of agricultural research, would involve:

(a) An expansion of the cooperative work with the several States which may include the assignment of personnel working on the real problems of their areas under cooperative relationships with the directors of the State agricultural experiment stations.

In connection with this projection of the findings obtained at a laboratory such as we have out here in the field, I'm going to be quite specific on one particular thing, and probably a lot of us - maybe the soils men here - will disagree, and some of my staff probably will think that I ought to remain just as a bottleneck up there and not be saying what ought to be done out here. I do want to second, however, what was said about at least giving very serious consideration to the possibilities and limitation of a standardized penetrometer. I still remember a visit to the Army Engineers station over at Vicksburg and some very convincing demonstrations that were put on that day, and I still hark back to some earlier work when I was with a State experiment station where I found that it was possible to get reasonably good correlations between various kinds of penetrometers--none of them as good as are now available--and some of the performance characteristics of pneumatic tires. I grant it is an empirical method and that it doesn't really say anything, except that a given soil would probably offer about a certain level of traction support, of rolling resistance, or tillage resistance. However, if we are going to take advantage of some of the short cuts that Worthington suggested by using electronic equipment, we are going to have to have more usable information of one kind or another about various soils and various conditions over the country to feed into electronic equipment.

(b) Some type of a nationally coordinated program in which the Laboratory would provide highly specialized year-round facilities and personnel not otherwise available.

(c) The establishment of a mechanism or systematic means of continued cooperative planning with industry. The objective of such an arrangement would be to make the Laboratory program more effective in meeting problems where it is competent to serve and in such a way as to most effectively complement and supplement the research activities of cooperating public agencies and industry.

I think that I ought to make a general comment here to repeat what I mentioned in short discussions with one or two of you in industry yesterday. We are going to give immediately consideration to the setting up of an Advisory Committee of some type for the Tillage Machinery Research Laboratory. That particular committee will, of course, have to be established within the framework of the policy of the Department of Agriculture. It will be a committee appointed either by the Director of the Laboratory here or by somebody in the Agricultural Research Service, but we make the assumption that it will include representation from other public research agencies and from industry, and from agriculture. I'm not prepared to say just how and in what way. In general, however, individuals would be on the committee as individuals--an individual assumed to be there because he did have competence and understanding in a certain area--but not necessarily

representing one group in opposition to another. I also want to point out that so far as I know it still is an American prerogative for any organization to form a committee on anything, and certainly there is no reason why any group that is interested in the activities of our group or our work here shouldn't set up a committee to assist in carrying out the relationship between the two groups. I do want to emphasize that we are very glad to have suggestions from any group, that we will certainly give them consideration. As has been said by some advertisers, "If you don't like what we're doing we wish you would tell us; if you do, tell all your friends and everybody else about it." We think that is possibly the best way to handle the situation.

It will, of course, be some time before the resources required for the complete implementation of this kind of a program we have just mentioned here, are available. In the meantime, every effort will be made to most fully and effectively utilize the present staff, equipment, and facilities and to guide expansion so as to most adequately serve the national need. Actually, this goal has been the purpose of this particular Seminar.

There is one other matter that should be considered. "Research is people." Good research requires the best people with the best training. It should be emphasized--and in this I want to go along with what Dr. Byerly said yesterday at the luncheon--that the Agricultural Research Service is making an all-out effort to develop a personnel program which will permit the recognition of basic scientific accomplishment independently of supervisory responsibilities. That kind of an ideal situation isn't going to happen overnight, but doubtless Administrator Shaw and, as seems likely, other supervisors all the way down, are sincere in their feelings that they wish to have that kind of a situation develop. As a part of this program, the National Tillage Machinery Laboratory is committed to the support of every practicable means permissible within the framework of USDA policy of improving the scientific training of its staff and committed to cooperate, in so far as regulations permit, with the Alabama Polytechnic Institute and other State colleges and universities in making the Laboratory's facilities available for graduate study research thesis projects where such projects are an appropriate segment of the Laboratory's over-all research program. In this connection, we are very happy to note that the Alabama Polytechnic Institute is making definite progress--maybe I'm jumping the gun a little bit, Fred, in mentioning it--but we believe that a doctoral program in the general area of soil mechanics is going to be a reality before too long. We have one of our staff members who is taking formal course work, he has enough confidence to be anticipating that this is going to be the case.

Dr. Nichols: Thank you, Dr. McKibben, for your far reaching, complete, and challenging program outlined for the National Tillage Machinery Laboratory. We look forward with great anticipation to the expansion in both facilities and personnel and to being able to more nearly fulfill the job for which this Laboratory was planned.

Now before we adjourn, are there any questions?

A speaker from the floor addressed a question to Mr. Worthington, and asked if his research group had a set of values for measuring the soil characteristics for use in the evaluation of the over-all performance of a tractor.

Mr. Worthington replied that, at the present time, the system was very haphazard, but that they were looking forward to the establishment of such a set of values.

Dr. Cooper asked Dr. Yoder to discuss any characteristics that we have today to describe a soil before and after tillage operations.

Dr. Yoder stated that he feels that the status of this is pretty pathetic, and suggested the possibility of a group of soils men being assembled for the purpose of trying to establish such a set of measurements. He commented that this procedure has been used in other areas of research to establish at least tentative standards as a common basis for working on research problems.

Mr. Bekker discussed the subject of soil strength and soil-vehicle relationships and stated that work at the Detroit Arsenal has produced equations, based on seven parameters, which may be used to predict the performance of tires, tracks, and vehicles. Instruments also have been developed to measure the parameters used.

Mr. Nitshke (Goodyear) mentioned having seen the tires and disks used in cooperative work at the Laboratory and asked for citation of other examples of work initiated by industry.

Dr. Cooper replied by mentioning the work on standardization of the type of bolt holes and the number of holes in disk plow disks for the international markets. He then discussed a procedure to be followed by anyone interested in setting up cooperative work at the Laboratory. Specifically, submission of a proposal to the Director of the Laboratory who will evaluate it and incorporate such work into the over-all work program if suitable. Also included in his remarks was the statement that it is desirable to have a representative of the cooperating company or agency at the Laboratory during at least part of the time when such work is in progress.

Mr. Pinches added the comment that, speaking as a representative of the Agricultural Research Service Administrator, he wanted to encourage individuals or groups to come to the Laboratory or other USDA locations with specific problems for cooperative research. He cited cases where specific varieties of crops, or types of insecticides, or other things developed by USDA research personnel must be produced by cooperative industry in order for the research results to become available to the American farmers.

Dr. Nichols added his invitation, as Director of the Laboratory, for everyone to bring problems, cooperation, or advice so that the Laboratory can do its most effective job for the public through industry.

Dr. Buchele stated that the Agricultural Engineering Department of Michigan State University was well satisfied with the cooperation between a graduate student from that school and the Laboratory, and that very good results had been obtained in a cooperative project.

Mr. Tanquary cited work on disk tests and the testing of moldboard plow bottoms as cooperative projects with which he personally had been associated. He stated that these problems had been suggested and that cooperation from the Laboratory had been readily obtained. He also suggested that there might be ways in which industry could be of assistance to the Laboratory by furnishing specific items that would be very valuable but difficult to obtain or to fabricate by the Laboratory. In addition, he added his emphasis to the value of personal discussion between company representatives and the staff members of the Laboratory who are working on the specific project.

Mr. Hanson expressed the desire of his Company to cooperate with the work of the Laboratory, and noted the present indications of such cooperation. He also commented on the basic statement relative to cooperative research in the field of farm equipment which has been published by the Farm Equipment Institute, and stated that anyone interested could obtain a copy of this statement.

After a brief statement of appreciation to those attending the meeting for their time, attention, and contributions, Dr. Nichols invited everyone to visit the Laboratory whenever possible. He then declared the Seminar adjourned.

Agriculture - Washington